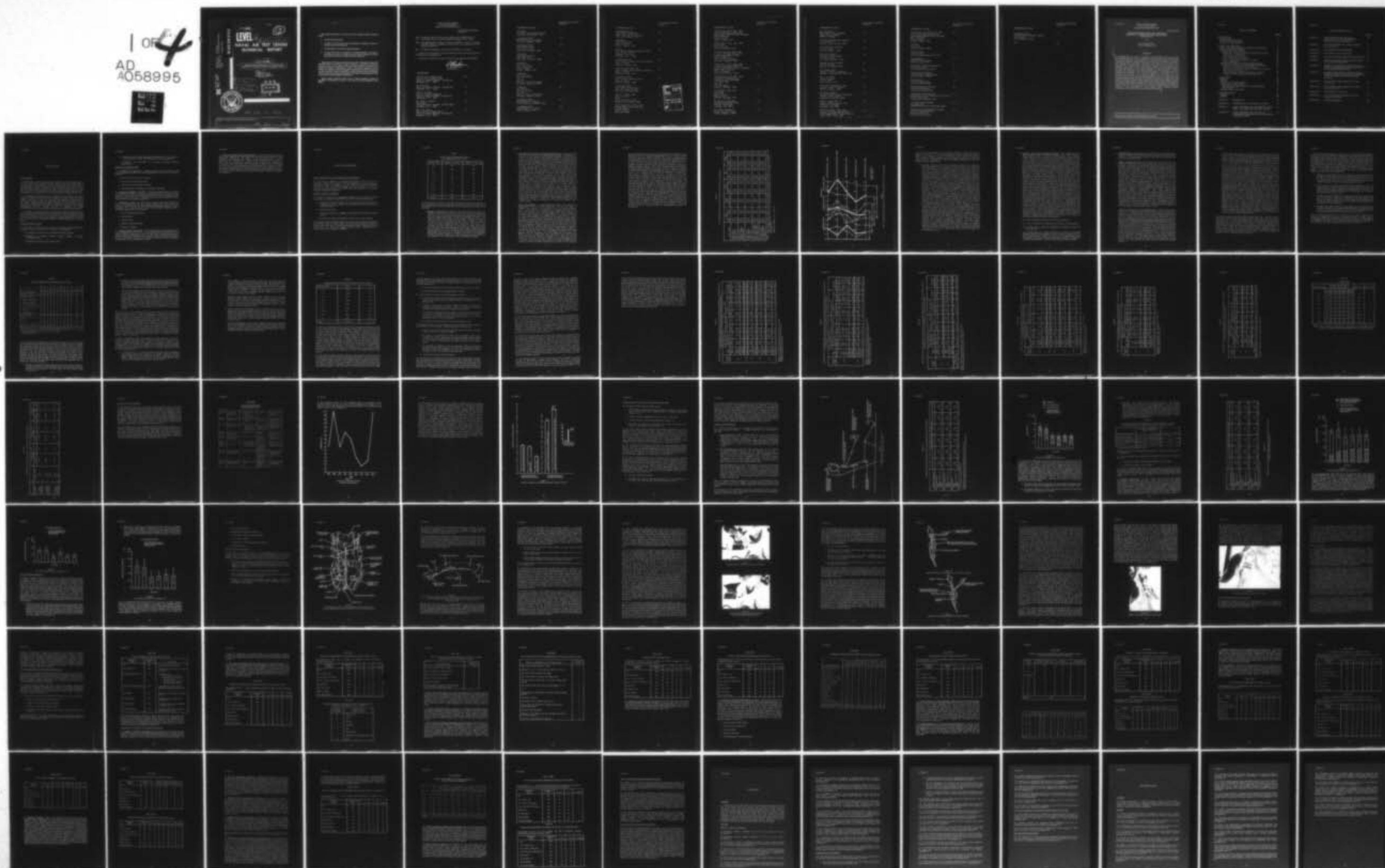
AD-A058 995 NAVAL AIR TEST CENTER PATUXENT RIVER MD F/G 1/3
AIRCREW PERSONNEL RESTRAINT SUBSYSTEMS DEFINITION OF DEFICIENCI--ETC(U)
AUG 78 R BASON, J ETHEREDGE
UNCLASSIFIED NATC-SY-28R-78 NL

1 OF 4
AD
A058995



OF 4

8995

COPY 122

# LEVEL II

(14) NATC-SY-28R-78

# NAVAL AIR TEST CENTER TECHNICAL REPORT

REPORT NO: SY-28R-78
AIRTASK NO: A531-5312/0535/6531000001
WORK UNIT NO:
DATE: 24 August 1978

AD A058995

(12)

B.S.

(9) FINAL REPORT

(6) AIRCREW PERSONNEL RESTRAINT SUBSYSTEMS DEFINITION OF DEFICIENCIES AND REQUIREMENTS.

by

(10) LT R. Bason, USN
HM2 J. Etheredge, USN

(11) 24 Aug 78

(12) 216p.





78 09 21 001



246 750

Part I indicates a deficiency, the correction of which is necessary because it adversely affects:

a. Airworthiness of the aircraft.

b. The ability of the aircraft (or piece of equipment) to accomplish its primary or secondary mission (or intended use).

c. The effectiveness of the crew as an essential subsystem.

d. The safety of the crew or the integrity of an essential subsystem. In this regard, a real likelihood of injury or damage must exist. Remote possibilities or unlikely sequences of events shall not be used as a basis for safety items.

Part II indicates a deficiency of lesser severity than a Part I which does not substantially reduce the ability of the aircraft or piece of equipment to accomplish its primary or secondary mission, but the correction of which will result in significant improvement in the effectiveness, reliability, maintainability, or safety of the aircraft or equipment. A Part II deficiency is a deficiency which either degrades the capabilities of the aircraft or equipment or requires significant operator compensation to achieve the desired level of performance; however, the aircraft or equipment being tested is still capable of accomplishing its mission with a satisfactory degree of safety and effectiveness.

Part III indicates a deficiency which is minor or slightly unpleasant or appears too impractical or uneconomical to correct in this model, but should be avoided in future designs.

NAVAL AIR TEST CENTER
NAVAL AIR STATION
Patuxent River, Maryland 20670

A53153120535/6531000001
SY-28R-78

From: Commander, Naval Air Test Center, Patuxent River, Maryland 20670
To: Commander, Naval Air Systems Command, Washington, D.C. 20361

Subj: NAVAIRTESTCEN Technical Report SY-28R-78, Aircrew Personnel Restraint Subsystems Definition of Deficiencies and Requirements, Final Report; transmittal of

Ref: (a) AIRTASK Assignment A53153120535/6531000001 of 1 Apr 1976

1. Reference (a) authorized a study of personnel restraint subsystems definition of deficiencies and requirements.

2. This report documents the results of the study and completes the AIRTASK.

R. L. Breckon

R. L. BRECKON
By direction

DISTRIBUTION:

| | |
|---|---|
| CAPT James B. Wildman, USN<br>Director, Crew Systems Division<br>Naval Air Systems Command - NAVAIR-531<br>Washington, D.C. 20631 | (15) |
| Mr. Fred Guill<br>Naval Air Systems Command - NAVAIR-531C<br>Washington, D.C. 20631 | (2) |
| CAPT N. B. Endo<br>Director, Program Management<br>Naval Air Systems Command - NAVAIR-532<br>Washington, D.C. 20631 | (1) |
| Mr. Henry A. Fedrizzi<br>Life Support<br>Naval Air Systems Command - NAVAIR-340B<br>Washington, D.C. 20631 | (1) |
| Mr. T. P. Mastic<br>Plans Policy and Program Branch<br>Naval Air Systems Command - NAVAIR-4111<br>Washington, D.C. 20631 | (1) |

DISTRIBUTION: (Cont'd)

| | |
|---|---|
| Commander<br>U.S. Naval Air Development Center<br>Warminster, Pennsylvania 18974 | (4) |
| Commanding Offiver<br>National Parachute Test Range<br>El Centro, California 92243 | (4) |
| Commanding Officer<br>Naval Ordance Center<br>Codes 51, 512, 515<br>Indian Head, Maryland 20640 | (3) |
| Commander<br>Naval Weapons Center<br>Codes 6222, 3273<br>China Lake, California 93555 | (2) |
| Commander<br>Naval Air Force<br>U.S. Atlantic Fleet<br>Naval Air Station<br>Norfolk, Virginia 23511 | (4) |
| Commander<br>Naval Air Force<br>U.S. Pacific Fleet<br>Code 72<br>Box 1210<br>Naval Air Station, North Island<br>San Diego, California 92135 | (1) |
| Commander<br>Naval Air Force<br>U.S. Pacific Fleet<br>Box 1210<br>Naval Air Station, North Island<br>San Diego, California 92135 | (4) |
| Commanding General<br>Fleet Marine Force, Pacific<br>FPO San Francisco, California 96610 | (4) |
| Commanding General<br>Fleet Marine Force, Atlantic<br>Norfolk, Virginia 23511 | (4) |

A53153120535/6531000001
SY-28R-78

DISTRIBUTION: (Cont'd)

Commanding General (1)
Third Marine Aircraft Wing
Marine Corps Air Station, El Toro
Santa Ana, California 92709

Commander (4)
Naval Safety Center
Naval Air Station
Norfolk, Virginia 23511

Director (2)
Naval Weapons Engineering Support Activity
Codes ESA-11, ESA-19
Washington Navy Yard
Washington, D.C. 20374

Commanding Officer (1)
Naval Aerospace Medical Research Laboratory
Naval Air Station
Pensacola, Florida 32508

LCDR Paul Furr, MSC, USN (1)
Naval Aerospace Medical Research Laboratory
Naval Air Station
Pensacola, Florida 32508

Commanding Officer (1)
Naval Aerospace Medical Institute
Naval Air Station
Pensacola, Florida 32508

Commanding Officer (1)
Navy Fighter Weapons School
Naval Air Station, Miramar
San Diego, California 92145

CDR E. T. Smith, USN (1)
Executive Offiver
VF-43
Naval Air Station, Oceana
Virginia Beach, Virginia 23460

LCDR Harold Pheeny, MSC, USN (1)
Aviation Medical Safety Operations
Training Wing Six
Naval Air Station
Pensacola, Florida

DISTRIBUTION: (Cont'd)

LCDR D. Gary Smith, MSC, USN (1)
Aviation Physiology Training Service
Naval Regional Medical Center, Portsmith
Branch Dispensary
Naval Air Station
Norfolk, Virginia 23511

LCDR Robert L. Elzy, MSC, USN (1)
Branch Clinic
Naval Air Station
Jacksonville, Florida 32212

LT Charles Anderson, MSC, USN (1)
Aerospace Physiology Training Unit
Naval Regional Medical Center
Regional Dispensary
Naval Air Station, Miramar
San Diego, California 92145

LCDR Jerry C. Patee, MSC, USN (1)
Aerospace Physiology Training Unit
Naval Regional Medical Center, Long Beach
Marine Corps Air Station
El Toro Dispensary
Santa Ana, California 92709

LCDR David B. Kelly, MSC, USN (1)
Aeromedical Safety Operations
Commander Light Attack Wing
U.S. Pacific Fleet
Code 021
Naval Air Station
Lemoore, California 93245

LT Guy Banta, MSC, USN (1)
Code AMSO
Branch Clinic
Naval Air Station
Meridian, Mississippi 39301

Mr. Byron C. Solomonides (1)
Rockwell International Aircraft
4300 East Fifth Avenue
Columbus, Ohio 43216

Mr. Wolf J. Hebenstreit (1)
Boeing Aerospace Company
Seattle, Washington 98124

DISTRIBUTION: (Cont'd)

Mr. John Jewell (1)
Martin-Baker Aircraft Company
Higher Denham Uxbridge
Middlesex, England

Stencel Aero Engineering Corporation (1)
P.O. Box 5836
Asheville, North Carolina 28804

Stanley Aviation Corporation (1)
P.O. Box 20308
Denver, Colorado 80220

Mr. Robert Manzuk (1)
Teledyne Ryan Incorporated
2701 Harbor Drive
San Diego, California 92138

Northrop Aircraft Corporation (1)
3901 W. Broadway
Hawthorne, California 90250

Mr. Armand Aronne (1)
Grumman Aerospace Corporation
Bethpage, Long Island, New York 11714

Mr. E. R. Atkins (1)
Vought Corporation
P.O. Box 5907
Dallas, Texas 75222

Naval Plant Representative Office (1)
Lockheed Aircraft Corporation
Burbank California 91503

Mr. Robert McIntyre (1)
McDonnell Douglas Aircraft Corporation
Douglas Aircraft Company
Long Beach, California 90846

Ronald L. Huston Ph. D. (1)
College of Engineering, Loc #112
University of Cincinnati
Cincinnati, Ohio 45221

LCDR James Brady, MSC, USN (1)
Aerospace Physiology Training Branch
Naval Regional Medical Center (Code 08)
Corpus Christi, Texas 78419

DISTRIBUTION: (Cont'd)

| | |
|---|---|
| LCDR John F. Greear III, MSC, USN<br>Aviation Physiology Training Service<br>Naval Regional Medical Center, Postsmith<br>Branch Dispensary<br>Naval Air Station<br>Norfolk, Virginia 23511 | (1) |
| USAABAR<br>Fort Rucker<br>Dothan, Alabama 36360 | (1) |
| Dayton T. Brown<br>555 Church Street<br>Bohenia, Long Island, New York 11716 | (1) |
| Talley Industries<br>3800 North Central Avenue<br>Phoenix, Arizona 85012 | (1) |
| M. Steinthal & Company, Incorporated<br>2525 Palmer Avenue<br>New Rochelle, New York 10801 | (1) |
| Pacific Scientific Company<br>1346 South State College Boulevard<br>Anaheim, California 92803 | (1) |
| H. Koch & Sons<br>5410 E. LaPalma Avenue<br>Anaheim, California 92807 | (1) |
| Fairchild Industries, Incorporated<br>20301 Century Boulevard<br>Germantown, Maryland 20767 | (1) |
| Deputy Inspector General Safety<br>Headquarters, Air Force Inspection & Safety Center<br>Norton Air Force Base<br>San Bernardino, California 92409 | (1) |
| Aeronautical Systems Division<br>Life Support SPO<br>Wright-Patterson Air Force Base, Ohio 45433 | (1) |
| United States Air Force Systems Command<br>School of Aerospace Medicine<br>Brooks Air Force Base<br>San Antonio, Texas 78235 | (1) |

A53153120535/6531000001
SY-28R-78

DISTRIBUTION: (Cont'd)

| | |
|---|---|
| Commanding General<br>U.S. Army Aviation Systems Command<br>P.O. Box 209<br>St. Louis, Missouri 63166 | (1) |
| DDC | (12) |

SY-28R-78

NAVAL AIR TEST CENTER
NAVAL AIR STATION
Patuxent River, Maryland 20670

24 August 1978

# AIRCREW PERSONNEL RESTRAINT SUBSYSTEMS DEFINITION OF DEFICIENCIES AND REQUIREMENTS FINAL REPORT

by

LT R. Bason, USN
HM2 J. Etheredge, USN

## ABSTRACT

NAVAIRTESTCEN was tasked to examine reported problems with aircrew torso restraint garments. Five sources of information were used for the investigation into the reported problems: Development of a logic tree for analysis of reported inadequate restraint of aircrews; examination of Medical Officer's Reports from 1969 through 1976 pertaining to ejections from aircraft in which the MA-2 Integrated Torso Harness was a part of the restraint system; examination of Unsatisfactory Reports for the same period; solicitation of an Aircrew Personnel Restraint Questionnaire from aircrew assigned to high performance tactical aircraft; and a laboratory study of the biomechanics of -Gz restraint. The MA-2 Integrated Torso Harness was found to be inadequate in all respects for -Gz restraint and ineffective as a restraint garmet for -Gx and lateral (Gy) accelerative forces. Data were developed defining the effects of negative Gz upon the body, suggesting that it produces two separate components, off-seat travel and body stretch, each of which requires specific treatment by any proposed restraint system. Recommendations are made for immediate improvement of deficiencies in the design of the restraint harness and its related subsystems, and emphasis is placed on the need for reevaluation of restraint needs, mobility needs, and the comfort of the crewmember in future design efforts. Further research, development, and testing of a variety of harnesses is urged.

# TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

# INTRODUCTION

## BACKGROUND

1. Maneuvering control of high performance aircraft is extremely demanding of a pilot, and flight path orientation becomes highly erratic and unpredictable in departure from controlled flight. If a pilot is to maintain control of his aircraft in these situations, he must be adequately restrained. Inadequate aircrew restraint, especially under negative G, has been a topic of concern for the past few years. The interest is in the degradation of the pilot's ability to apply corrective action, read instruments, or reach ejection controls in inadequately restrained situations.

2. The problem of inadequate aircrew restraint is a very complex one in which cursory investigations reveal many, often complicated, causes. Over the years, a number of quick "fixes" have been developed and evaluated, and in many cases, incorporated without resulting in a major reduction in deficiency reports. One of the largest stumbling blocks preventing development of an effective aircrew restraint system has been the inadequate or improper definition of the problem. Consequently, NAVAIR, through reference 1 (appendix A), tasked NAVAIRTESTCEN to examine reported torso garment restraint system problems.

3. The purpose of this examination was to: (1) identify and define the deficiencies in crew restraint provided by the MA-2 Integrated Torso Harness (ITH) in all flight regimes; (2) evaluate the effects of these deficiencies on aircrew performance; and (3) develop aircrew personnel restraint subsystem design requirements for assuring the necessary restraint, comfort, and mobility in all flight regimes and at all crew stations.

## SCOPE OF INVESTIGATION

4. Five sources of information were utilized to investigate alleged problems of inadequate restraint of aircrews. These consisted of the following:

a. Development of a logic tree for analyzing inadequate restraint.

b. Examination of Medical Officer's Reports (MOR) of aircraft accidents/incidents.

c. Examination of Unsatisfactory Reports (UR's).

d. A laboratory study of body shift when transitioned from a +1 Gz load to a -1 Gz load. (For orientation of gravitational vectors, see appendix B.)

e. Development and solicitation of an Aircrew Personnel Restraint Questionnaire.

## METHOD OF INVESTIGATION

5. Development of a Logic Tree: A graphic analysis of major events that could lead to inadequate restraint was conducted (appendices C, D, and E). This analysis included:

a. Identification of items which could fail.

b. Reasons for the failures identified.

c. Direct effects of the failures identified.

d. Probable ultimate consequences of the failures identified.

6. Examination of MOR's: The MOR's of aircraft accidents/incidents associated with specific MA-2/MA-2P problems, environmental factors, and various flight attitudes were requested from the Naval Safety Center. The exact manner in which the Safety Center records were scrutinized and the specific information extracted from the MOR's are presented in appendix F.

7. Examination of UR's: The UR's for the calendar period 1969 through 1976 (coded as being associated with torso harness, lap belt, and ejection seat inertia reels) were requested from the Naval Weapons Engineering Support Activity in Washington, D.C., and the Naval Safety Center, Norfolk, Virginia. Specific information supplied by the UR's included:

a. Aircraft identification number.

b. Aircraft model.

c. Work unit code.

d. Manufacturer's Part Number.

e. Narrative of failure.

8. Laboratory Study of Body Shift: A study of body shift when restrained subjects were transitioned from a +1 Gz to a -1 Gz environment was conducted. Five male volunteer subjects, ranging from 10th to 91st percentile in weight and from 25th to 94th percentiles in seated height, were used in the study. Each subject participated in each of six different test protocols. A detailed description of the test equipment and procedures is given in appendices G and H.

9. Aircrew Personnel Restraint Questionnaire: An Aircrew Personnel Restraint Questionnaire (appendix I) was developed with the Naval Air Development Center, Warminster, Pennsylvania. The purpose of this questionnaire was to solicit information not obtainable from existing aircraft accident/incident reports. To insure that the questionnaire received proper attention and consideration, Aeromedical Safety Operations (AMSO) Physiologists administered and supervised the completion of the questionnaires. The questionnaire was distributed to Naval aviators and Naval flight officers flying tactical jet aircraft equipped with torso harness type restraint systems. A specific quantitative analysis of the questionnaire was conducted by the Naval Weapons Engineering Support Activity in accordance with appendix J.

# RESULTS AND DISCUSSION

## LOGIC TREE FOR ANALYZING INADEQUATE RESTRAINT

10. The logic tree approach for analyzing the potential causes and effects of inadequate restraint was utilized to aid in formulating a consistent pattern of investigative efforts to streamline the overall evaluation. Certain commonalities found in the logic tree provided valuable clues for examination of the vast quantities of data provided by the MOR's, UR's, and responses to the Aircrew Personnel Restraint Questionnaire.

## MEDICAL OFFICER'S REPORTS

11. In order to obtain the most meaningful data relevant to the objectives of this investigation, examination of the MOR's was confined to the following criteria:

a. Calendar period 1969 through 1976 (1 January 1969 was selected as a starting point in order to utilize the current format of Naval Safety Center computer printout).

b. Noncombat ejections.

c. Tactical jet aircraft (i.e., equipped with Integrated Torso Harness restraint system).

d. Aircrew successfully accomplished ejection (i.e., free of the aircraft).

12. Using the criteria described above, 920 ejections were examined involving 669 aircraft. The types of aircraft, number of aircraft involved, and the number of ejections from each type of aircraft are presented in table I. Aircraft such as the OV-10 (not a jet), AV-8 (not equipped with the MA-2 restraint), and S-3 (nontactical) are not included in this report.

Table I

Aircraft Type Composing Study Group
for Calendar Period 1969 - 1976

| Aircraft Type | Number of Aircraft | Number of Ejections |
|---|---|---|
| A-4 | 177 | 205 |
| A-7 | 136 | 136 |
| A-6 | 51 | 106 |
| F-4 | 157 | 271 |
| F-8 | 79 | 79 |
| F-9 | 16 | 28 |
| F-14 | 9 | 18 |
| A-5 | 16 | 32 |
| T-2 | 28 | 45 |
| TOTAL | 669 | 920 |

13. Five percent (46 cases) of the 920 ejecting aircrewmen were reported to have had problems with the torso garment. Of these 46 cases, 43 involved the MA-2 torso garment and 3 involved the MA-2P. Torso harness problems consisted of the following:

a. Damage to Torso Harness: Damage to the torso harness was coded in the MOR's in 1.9% of the ejections (17 cases). In all cases, the damage was reported to have been sustained during parachute opening shock. The most prevalent damage noted (16 of 17 cases) was the damage or failure of the Rigid Seat Survival Kit (RSSK) "retainer straps." Although no reference could be found to exactly define this term, these 16 reports cited loss of the RSSK (8 cases) or dangling of the kit in such a way as to make its contents unavailable during parachute descent (8 cases). In one case, stitching on the main sling above the chest strap on an MA-2P failed and the chest straps were forced up under the pilot's chin, causing discomfort. While damage to the MA-2 Integrated Torso Harness during parachute opening shock does not alter the restraint effectiveness of the garment during flight, the ensuing loss or dangling of the RSSK could compromise aircrew survivability through loss of survival equipment, nonavailability of the equipment, or by causing injury to the descending aircrewman.

b. Nonstandard Torso Harness Configuration/Modification: Approximately 2% (18 cases) of the ejectees had nonstandard torso harness configurations or modifications. The majority of the modifications (89%) consisted of pockets or loops sewn onto the torso harness for the purpose of carrying items of personal survival equipment. In one case, the pilot had his survival knife sewn to the harness webbing. During ejection, the knife separated from its sheath and flailed about the pilot's chest and face at the end of a lanyard. The pilot was not injured. Another reported ejection found the pilot wearing a modified MA-2 instead of an MA-2P over an antiexposure suit. The modification in this case consisted of an extension strap sewn to the chest strap to allow for adjustment over the bulky antiexposure garment. Other nonstandard configurations of the MA-2 torso harness involved one pilot wearing a torso harness designed for the Blue Angels Flight Demonstration Team and two other aircrewmen wearing torso harnesses modified to "improve Air Combat Maneuvering" (ACM). While the nature of this modification was not described in the MOR, communication with the Naval Safety Center indicated that the modification involved an authorized cutaway MA-2 to reduce the heat load on the wearer. While the aforementioned nonstandard torso garments did not appear to have compromised torso restraint in these specific instances, they do suggest that the SV-2B survival vest for carrying and stowing items of personal survival equipment is not meeting the needs of the aircrewman (assuming those needs to be valid), and the MA-2 torso harness does not fully satisfy the needs perceived by the aircrewman. The two cases of modified torso garments for improving ACM capability deserve special consideration. Any modifications designed to enhance in-cockpit mobility/comfort must be carefully assessed against compromise of cockpit and emergecy egress restraint needs.

c. Loose Torso Harness: A loose-fitting torso harness was reported for approximately 1.2% of ejecting aircrewmen (11 cases). Of these, 8 harnesses were alleged to be "oversized," one was not properly adjusted, and two aircrewmen were wearing MA-2P torso garments in lieu of the MA-2 torso garment over standard summer flight suits. Although the garment sizing discrepancies may have added to the comfort of the pilot, the results upon ejecting were multiple bruises to the body. No reasons were given in the MOR's as to why the eight torso harnesses were oversized but there are some plausible explanations. The Aviation Supply Office, Philadelphia, Pennsylvania, advises that the MA-2 Integrated Torso Harness has, on numerous occasions, been out of stock because of the lead time between availability of funds, letting of contracts, and delivery of items. The supply problem is further aggravated by the necessity to maintain a stock of 15 sizes of MA-2's and to procure a high number of spares to accommodate the aircrewmen's needs for larger size harnesses when flying with an antiexposure suit. The nonavailability of proper size torso harnesses and the requirement for some aircrewmen to maintain two MA-2's in order to accommodate their antiexposure suits may be forcing aircrewmen to accept whatever is available: i.e., a larger size than the correct one. The MA-2 torso harness should fit the wearer snuggly in order to minimize injury from parachute opening shock. Table II (taken from the Aviation Crew Systems Manual (Parachutes), NAVAIR 13-1-6.2) presents

the torso dimensions for the selection of proper size MA-2 Integrated Torso Harness by an Aircrew Survival Equipmentman (PR). As can be seen from this table, there are currently 15 harness sizes based on 5 anthropometric parameters. When this table is followed in selecting the garment, and it is properly adjusted by the wearer, the result should be a snug fitting MA-2. A survey of torso harness fitting procedures (questions 5 and 6 of appendix I) indicates only 66% of the aircrewmen are fitted by a parachute rigger, presumably using the Aviation Crew Systems Manual as a guideline. In many instances, however, even when the table is used, the complex interrelationships among the sizing parameters make a "proper" fit difficult to obtain. For example, a 50th percentile man (reference 2 of appendix A) with a chest circumference of 38.88 in. (98.8 cm), vertical trunk circumference of 65.86 in. (167.3 cm), waist circumference of 33.61 in. (85.4 cm), hip circumference of 38.65 (98.2 cm), and thigh circumference of 22.64 in. (57 .5 cm) could be fitted with a medium, large, or extra large torso garment (figure 1). Past experience of the investigator and information from aircrews contacted by this investigator suggest that some crewmen would choose the large or extra large size for comfort (especially when worn outside the cockpit; e.g., ready-room, flight line). This practice not only degrades the MA-2 as a parachute harness (allowing greater opening shock effect), but also as a cockpit restraint system since it prevents a man with a small girth from fully tightening his lap belt as he is now equipped with a larger lap belt (paragraph 54). If adequate multiple adjustment features could be incorporated in the garment design, the logistics problems and the complex fitting procedures described above could be greatly alleviated by reducing the number of torso garment sizes stocked. Such an approach would also serve to reduce the number of "wrong" choices available to the aircrewman while providing better fit and greater availability. It is recommended that the feasibility of fewer torso garment sizes with proper location of multiadjustment features be investigated.

Table II

MA-2 Integrated Torso Restraint Garment Sizes and Torso Dimensions

| MA-2 Sizes | Chest Circumference MIN | Chest Circumference MAX | Vertical Trunk Circumference | Waist Circumference MIN | Waist Circumference MAX | Hip Circumference MIN | Hip Circumference MAX | Thigh Circumference MIN | Thigh Circumference MAX |
|---|---|---|---|---|---|---|---|---|---|
| Small Short | 33.0 | 37.0 | 61.0 | 26.0 | 30.0 | 34.0 | 38.0 | 19.0 | 23.0 |
| Small Regular | 33.0 | 37.0 | 64.0 | 26.0 | 30.0 | 34.0 | 38.0 | 19.0 | 23.0 |
| Small Long | 33.0 | 37.0 | 66.0 | 26.0 | 30.0 | 34.0 | 38.0 | 19.0 | 23.0 |
| Medium Short | 35.0 | 39.0 | 63.0 | 28.0 | 33.0 | 34.5 | 39.5 | 20.0 | 24.0 |
| Medium Regular | 35.0 | 39.0 | 65.0 | 28.0 | 33.0 | 34.5 | 39.5 | 20.0 | 24.0 |
| Medium Long | 35.0 | 39.0 | 67.0 | 28.0 | 33.0 | 34.5 | 39.5 | 20.0 | 24.0 |
| Large Short | 37.0 | 43.0 | 65.0 | 32.0 | 37.0 | 37.0 | 42.0 | 21.0 | 25.0 |
| Large Regular | 37.0 | 43.0 | 67.0 | 32.0 | 37.0 | 37.0 | 42.0 | 21.0 | 25.0 |
| Large Long | 37.0 | 43.0 | 68.0 | 32.0 | 37.0 | 37.0 | 42.0 | 21.0 | 25.0 |
| Extra Large Short | 38.0 | 45.0 | 66.0 | 34.0 | 40.0 | 38.5 | 45.5 | 22.0 | 26.5 |
| Extra Large Regular | 38.0 | 45.0 | 68.0 | 34.0 | 40.0 | 38.0 | 44.0 | 22.0 | 26.5 |
| Extra Large Long | 38.0 | 45.0 | 70.0 | 34.0 | 40.0 | 38.0 | 44.0 | 22.0 | 26.5 |
| XX Large Short | 40.0 | 48.0 | 72.0 | 36.0 | 42.0 | 39.0 | 46.0 | 24.0 | 30.0 |
| XX Large Regular | 40.0 | 48.0 | 74.0 | 36.0 | 42.0 | 39.0 | 46.0 | 24.0 | 30.0 |
| XX Large Long | 40.0 | 48.0 | 76.0 | 36.0 | 42.0 | 39.0 | 46.0 | 24.0 | 30.0 |

NOTE: Data obtained from Aviation Crew Systems Manual (Parachutes) NAVAIR 13-1-6.2 of December 1974. Data for Extra-Extra Large (XX) sizes obtained from proposed revision to NAVAIR 13-1-6.2 of December 1977

Metric conversion: 1 in. = 2.54 cm

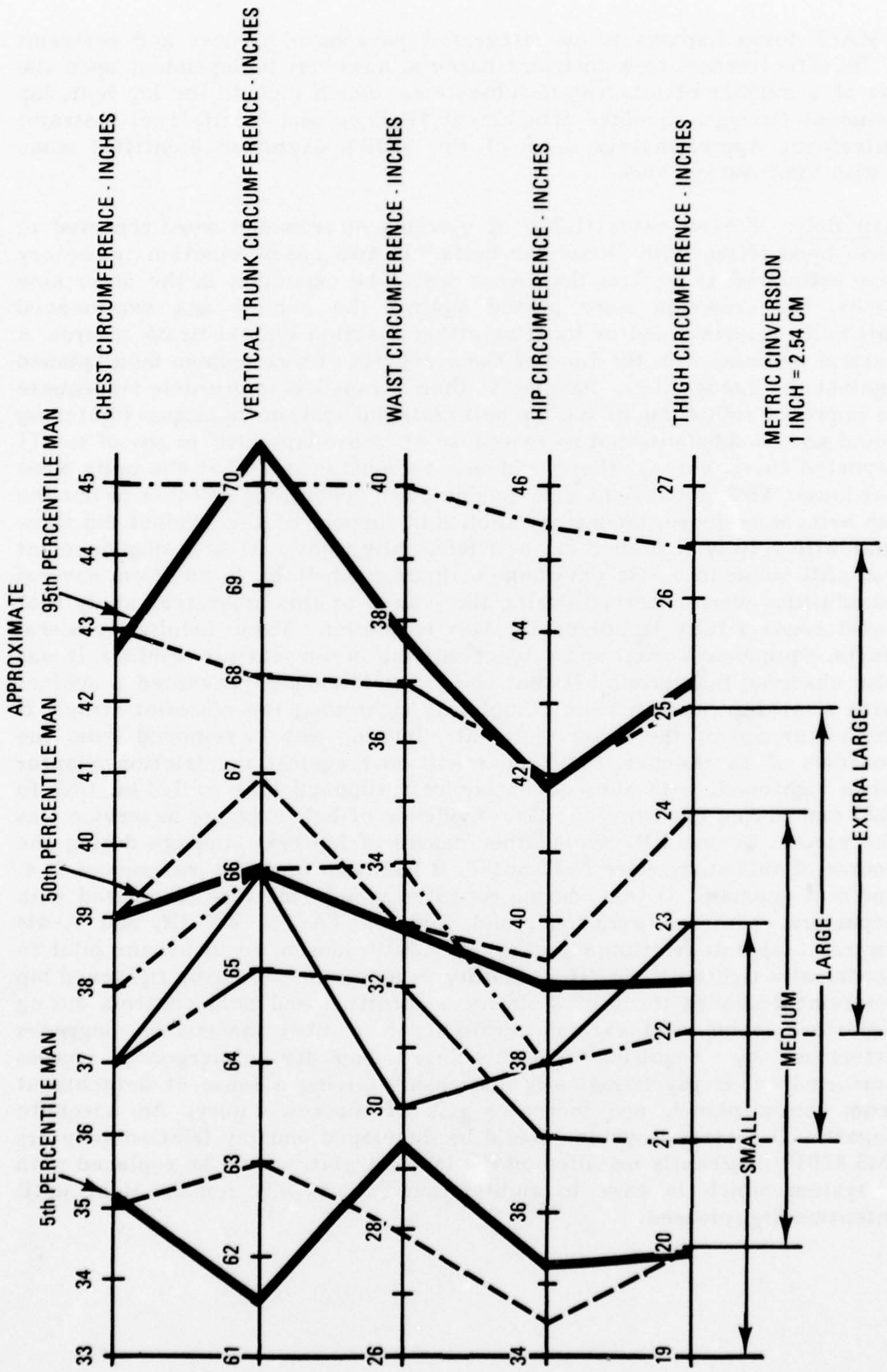



Figure 1
MA-2 Sizing Parameter Applications to 5th, 50th, and 95th Percentile Size Groups

14. The MA-2 torso harness is an integrated parachute harness and restraint garment. Its effectiveness as a restraint harness, however, is dependent upon the proper use of a number of integrated subsystems which include the lap belt, lap belt attachment fittings, shoulder attachment fittings, and inertia reel restraint system interface. Approximately 2.7% of the MOR's examined identified some problems with these subsystems.

a. Lap Belt: Eleven cases (1.7%) of ejecting aircrewmen were reported to have been flying with "loose lap belts." In two cases, ejection trajectory was estimated to be less than what would be expected. In the other nine cases, the crewmen were pinned against the canopy and experienced difficulty reaching and/or locating either ejection system firing control. A natural inclination in the face of these reports of aircrewmen being pinned against the canopy (i.e., "hanging in their straps") is to presume inadequate or improper tightening of the lap belt restraint system. Improper tightening could not be substantiated as the cause of "loose lap belts" in any of the 11 reported cases, nor was there evidence to substantiate that the belts were not loose. While MOR data were inconclusive concerning whether or not the lap belts were loose, laboratory studies in support of this project did show that with a fully tightened lap belt (unusually tight), off-seat displacement can still occur in a -Gz environment (paragraph 36.b). In addition, several possibilities were observed during the course of this laboratory study that could cause a fully tightened lap belt to loosen. These involved visceral shifts, equipment shifts, and subject shifting in the seat for comfort. It was also observed (paragraph 54) that the lap belt keeper prevented a subject with small hip breadth from completely tightening the restraint straps. If the bitter end of the lower restraint adjusting web is removed from the confines of the keeper, the keeper will butt against the friction adapter when tightened, with subsequent lap belt slippage (1/4 to 1/2 in. (.63 to 1.27 cm) during exposure to -Gz. Evidence of belt slippage in service was the subject of one UR. While other causes of lap belt slippage during the course of this study were NOT noted, it has been reported (references 3, 4, and 5 of appendix A) that, during repeated violent motions associated with departure, poststall gyrations, and spins in TA-7C, TA-4F, and A-4M aircraft, lap belt friction adapters (MS 22019) loosen, requiring the pilot to continually tighten them. The inability to maintain a securely tightened lap restraint degrades the pilot's ability to position and hold controls during departure, spins, and various aerobatic/air combat maneuvers, degrades attention by requiring retightening, degrades emergency egress performance, is psychologically distressing (giving a sense of detachment from the airplane), and increases risk of aircrew injury. An adequate negative G restraint system should be developed and the friction adapters (MS 22019), currently installed on the lap restraint, should be replaced with a system which is easy to tighten and which will remain tight until intentionally released.

b. Parachute Riser Release (Shoulder) Fittings: Three aircrewmen were reported to have flown with unlocked parachute riser release (shoulder) fittings. While all these aviators received fatal injuries, only one fatality could be attributed solely to failure to fasten the shoulder fittings. In this case, the failure to lock the fittings may have been habitual as the pilot had been observed on at least one other occasion to have flown with the shoulder fittings unlocked. The second aviator sustained fatal injuries when the aircraft impacted the ground following a mid-air collision. The MOR noted, however, that even if the pilot had had time to eject, he would not have survived since he had disconnected his shoulder fittings prior to the mishap. The MOR speculates that the pilot released his shoulder fittings in flight so he could have more freedom of movement during air combat maneuvers. The third fatality involved a student Naval Aviator who attempted an unauthorized rolling maneuver at low altitude (100 ft AGL) and flew the aircraft in such a manner as to preclude recovery. The student ejected inverted and received fatal injuries. Investigation of this accident revealed the right shoulder fitting to be disconnected. The MOR reported that the plane captain connected the aviator's left fitting and the pilot connected (or attempted to connect) the right shoulder fitting. The question posed by this accident is not whether the pilot would have survived had his right shoulder fitting been fastened (since he obviously ejected outside the envelope), but WHY the fitting was found disconnected. It is quite possible that the right shoulder fitting failed as a result of ejection forces or ground impact. It is also possible that the shoulder fitting was not securely fastened. Since parachute opening did not occur prior to ground impact, the failure probably was not associated with the forces generated by parachute opening shock. Past experience of this investigator and information from aircrewmen contacted by this investigator indicate that if the locking bar of the shoulder fitting is in the DOWN position, the fitting can "snap" in and give a false sensation of being LOCKED but will permit separation when tension is applied. This problem could be alleviated to some extent by making the locking bar more noticeable when in the unlocked position. A more detailed description of inadvertent failure of the shoulder fittings is given in paragraph 58. An in-flight failure of shoulder fittings, for any reason, results in loss of attachment to the parachute and forfeiture of upper torso -Gx restraint. The decision of an aviator to knowingly abandon his shoulder fittings suggests:

(1) A lack of training in the proper use of the torso garment.

(2) A lack of supervision or enforcement in the proper use of the garment.

(3) A system that is restrictive, degrading pilot mobility necessary for successful ACM.

It is recommended that a positive indication of locking of the shoulder fittings be provided and compliance with procedures for proper use of the MA-2 Integrated Torso Harness be reviewed on a frequent basis by local commands. It is further recommended that aircrew needs for both mobility and upper torso restraint be reviewed, emphasizing all phases of flight.

c. Lap Belt Fittings: Following an ejection from an A-6, one aircrewman was reported to have lost his seat pan survival kit because his "lap belt became unlatched." No explanation was given in the MOR for this inadvertent release of the lap belt fitting.

d. Shoulder Strap Inertia Reel: Eleven aircrewmen were reported in the MOR's to be flying with an unlocked shoulder strap inertia reel. The most prevalent reason given for the unlocked inertia reel was to allow more freedom of movement during ACM. Two aircrewmen admittedly forgot to lock the inertia reels prior to a test maneuver because of distraction. Theoretically, an unlocked inertia reel should not present any restraint difficulties if it functions properly when called upon. Seven of the eleven aircrewmen, however, were reported to have encountered restraint problems due to unlocked inertia reels. All seven were thrown far forward in the cockpit by G forces. Five sustained head injuries as a result of striking the instrument panel. Two other aviators, both in the same aircraft, were extremely malpositioned for ejection. The pilot of this aircraft, because of his forward position, could not apply proper control inputs and experienced difficulty initiating command ejection. The fact that all seven aviators were well forward in the shoulder restraint straps could be interpreted as a design problem of the automatic inertia locking mechanism. Military specifications since 1952 (MIL-R-8236, MIL-D-81514B) direct that "the inertia-locking mechanism effectively and positively lock. . .when subjected to an inertial component of 3 G's or more" but not less than 2.0 G's. The sensing mechanism for the automatic inertial locking feature is actuated by the rate of webbing or cable payout and not by acceleration forces acting on the inertia reel itself. If the onset of longitudinal G forces is slow enough, the rate of webbing payout may be insufficient to actuate the automatic locking mechanism, resulting in complete payout before the system locks. This problem was substantiated by one accident, an excerpt of which is given below:

"During a test maneuver investigating high angle of attack characteristics of the F-14A, a departure from controlled flight occurred which progressed rapidly into a flat spin. Having entered into the maneuver without harness locked, the pilot and flight officer were immediately malpositioned in their respective cockpits as the increasing G forces moved them forward in their harnesses. Movement forward was at too slow a rate, however, to activate the inertia reel lock feature of the shoulder harness system. Subjected to almost 7 G's "eyeballs out," the pilot was, for all practicable purposes, completely incapacitated from the high G forces. The location of the upper escape handle precluded its use by the pilot who was held forward by the G forces and could not reach the upper handle. The lower handle was difficult to reach because the pilot was displaced forward over the handle due to G forces and his survival wet-suit hampered access to the lower handle. Because of this position, the pilot was able to exert very little upward pull on the lower handle. Although the pilot tried to eject starting at 28,000 ft, he was unable to do so until approximately 13,000 ft where G forces reduced to 4 G's. The apparent position of the pilot and flight officer during ejection was fully forward and firmly into the unretracted shoulder harness."

In this accident, the average rate of change of the longitudinal acceleration was 0.2 G/sec. At this rate of change, it takes 10 sec to reach 2 G's and 15 sec to reach 3 G's, within which limits the inertial locking mechanism should "effectively and positively" lock. However, the webbing in the F-14 is 18 in. long, an extension achievable in approximately 0.2 sec at 2 to 3 G's. At a rate of onset of 0.2 G/sec, the strap in the F-14 would completely pay out in less than 1 sec ($s = \frac{1}{2} at^2$) assuming no effort on the part of the pilot to resist his forward movement. Since this particular pilot's attention was directed at the task of regaining control of his aircraft, it is safe to conclude that payout of the strap was completed several seconds before the inertial locking mechanism would have functioned. In this accident, it is probable that the inertia reel did function according to specifications and that there was no technical problem with the automatic inertial locking mechanism, but circumstances overcame the design capabilities. The decision of the pilot to fly with an unlocked inertia reel does suggest, however, that the inertia reel requirements fail to adequately consider trade-offs between upper torso restraint and aircrew mobility. It is recommended that aircrew needs for upper torso restraint and mobility throughout all phases of flight be reevaluated and efforts be directed at providing restraint systems and subsystems which meet these needs. In addition, pilots who perform spin test maneuvers or other flight test maneuvers need to utilize a premaneuver checklist to insure a locked retraction mechanism. The need for this premaneuver checklist is further substantiated by the loss of yet another F-14A which departed controlled flight during a test maneuver and progressed into a flat spin. Again, the pilot was thrown forward in his shoulder restraints by G forces. While hanging in his straps, the pilot cycled his harness lock lever to assure himself that it was locked and inadvertently unlocked it. Had a premaneuver checklist (including "harness locked") been utilized, the pilot might not have been concerned with his harness lock lever. However, a premaneuver checklist is not feasible for actual combat and aggressive combat training; hence, many potential exposures to this problem can be covered only through thorough design consideration of the dichotomous needs of the pilot--mobility and restraint.

15. In the calendar period from 1969 through 1976, there were 100 ejections (approximately 11% of the total number of ejections) in which adverse G forces were coded as a factor during attempted control or egress from an uncontrolled or disabled aircraft. In 52 of these ejections, it was specifically noted that the aircrewman was greatly hindered in his attempt to control the aircraft and to initiate ejection, either because of being pinned against the canopy by negative G forces, flung around the cockpit by violent lateral buffeting forces, or incapacitated by positive G forces. This points out that at least one of every two ejectees who encountered adverse G forces while in uncontrolled flight was reported severely compromised in his performance.

16. Table III shows a breakdown, by aircraft, of the egress and control problems encountered as a result of adverse G loads. Fifty-one aircrewmen were reported to be "hanging in their straps" because of negative G forces. In 18 of the 51 ejections (35%), this condition prevented the use of the face curtain ejection firing control and required the use of the lower ejection firing control. Difficulty reaching or activating the face curtain was reported in 23 other cases (45%). Four cases reported difficulty in reaching or locating the lower ejection handle and three cases were unable to use the lower ejection handle and required the use of the face curtain. The following are excerpts taken from some of the MOR's in which negative G forces were specifically reported as factors in egress difficulties. Additional excerpts are shown in appendix K.

a. "During an aircraft maneuver in an A-7 aircraft, the pilot allowed aircraft to depart controlled flight. He became disoriented and could not recover. He elected to eject but, due to a loose lap belt and negative G forces, he was pushed up and away from the seat and could not activate the face curtain. He managed to reach the alternate handle and eject."

b. "Pilot of this A-4 aircraft encountered violent negative G's when his aircraft departed controlled flight and entered an inverted spin. Pilot was thrown forward into glare shield and was pinned against the canopy. Pilot experienced some difficulty reaching lower firing handle due to negative G's pinning him against the canopy."

c. "During an instrument flight, this A-7 aircraft experienced an explosion and loss of control. Due to negative G's raising him off the seat, pilot reached for but was unable to grasp the seat firing handle. He held himself down with the left hand and reached for the face curtain with the right hand. He then pulled down with both hands."

d. "During an air combat maneuver training flight, this F-8 aircraft entered uncontrolled flight. Pilot became jammed upward into the canopy bow with his head tucked down and slightly to the left. Pilot was able to push away from the canopy into his seat. He ejected via the face curtain."

The most striking thing observed in the excerpts was the number of times that the aviator was "hanging in his straps," often pinned against the canopy, and the resulting undesirable body positions from which the pilot had to eject. The emphasis on "hanging in the straps" is given because it directly implies a degradation of aircrew ability to perform, especially when an ejection is called for.

## Table III

### Reported Problems Associated with Adverse G Forces

| Problem | Aircraft Type | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A-4 | A-7 | A-6 | F-4 | F-8 | F-9 | F-14 | T-2 | A-5 | Total Ejections | Total Problems |
| Ejections Involving "Hanging in Straps" Due to Negative G | 14 | 8 | 7 | 3 | 5 | 4 | 6 | 4 | 0 | 51 | |
| Distribution of Problems Associated with "Hanging in Straps" | | | | | | | | | | | |
| Difficulty Reaching/Locating Upper Ejection Handle (UEH) | 7 | 1 | 3 | 2 | 2 | 1 | 4 | 3 | 0 | | 23 |
| Unable to Reach Upper Ejection Handle, Had to Use Lower Ejection Handle (LEH) | 3 | 6 | 0 | 1 | 2 | 3 | 2 | 1 | 0 | | 18 |
| Difficulty Reaching/Locating LEH | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | | 4 |
| Unable to Reach LEH, Used UEH | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | | 3 |
| Unable/Degraded Ability to Control Aircraft | 4 | 2 | 0 | 1** | 3** | 1 | 1 | 4 | 0 | | 16 |
| Additional Problems | | | | | | | | | | | |
| Could not Eject due to Adverse G Forces | 0 | 0 | 1* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Seat Slap | 3 | 1 | 0 | 6 | 0 | 1 | 1 | 1 | 0 | 13 | 13 |
| Torso Injuries Due to Ejection Forces | 20 | 15 | 11 | 22 | 8 | 4 | 5 | 6 | 2 | 93 | 93 |
| Injuries Due to Poor Body Position | 17 | 12 | 19 | 14 | 6 | 8 | 2 | 6 | 1 | 85 | 85 |
| Total Problems by Aircraft | 56 | 38 | 39 | 47 | 21 | 18 | 15 | 21 | 3 | | 256 |

*F-4 accident associated with positive G forces in which RIO initiated ejection because pilot was incapacitated.
**F-4 and one F-8 accident associated with positive G forces; one F-8 accident associated with lateral G forces.

**17. In each of the above-mentioned cases, the pilot was able to eject, even though he was presented with a difficult egress situation, receiving in many cases injuries due to poor body position and ejection forces. There is evidence, however, to suggest that inadequate restraint possibly contributed to the loss of at least four aviators during this period. Two of those aviators were unable to initiate ejection because of adverse G forces and inadequate restraint and sustained fatal injuries in the subsequent crash. The two others sustained fatal injuries when their aircraft impacted the ground following loss of control during low level flight. These fatalities and other aircraft accidents in which the crew did not survive to report restraint problems are NOT included in the ejection statistics presented in this report. The following excerpts taken from the MOR's are presented here as testimony to the above statements.**

**a. "During a 5 G pullup, the right wing separated from the aircraft. Failure of the pilot and B/N to eject is believed to be due to instantaneous lateral and inverted G's, throwing pilot and B/N around in their straps, causing incapacitation."**

b. "Sudden loss of power during landing approach and the aircraft impacted the water. Pilot sustained fatal injuries when thrown through the canopy. Restraints were not attached though plane captain stated that the pilot was fully strapped in prior to taxi." MOR did not state which restraints were unattached nor whether the seat separated from the airframe.

c. "Aircraft struck ground short of runway due to fuel starvation. Instructor in rear cockpit attempted ejection at moment of impact; however, ejection sequence was not completed because of failure or damage to fully activate system. Student in front cockpit struck glare shield and sustained fatal head injuries. Student injury indicates possible inertia reel failure since inertia reel should have retracted when instructor pilot pulled seat firing handle sufficient to jettison canopy. Investigation also revealed student mini-Kochs were not fastened." MOR did not state whether seats separated from the airframe nor whether the seat design incorporated a time delay feature for the front seat which might have contributed to the inertia reel "failure."

These cases raise a very serious question. In how many other fatal, nonejection accidents was the aircrew, because of inadequate or improper use of restraint, unable to initiate ejection, or to survive ground impact of the aircraft? Under crash impact and absence of witnesses, reconstruction of such transitory aspects as departure from controlled flight and the effect of G's upon the aircrew become all but impossible. In the period examined (1969 through 1976), only in these four cases was there sufficient data to implicate poor restraint as a causative factor in the loss of the aircrewman. Inspection of the records for the period reveal that, in many cases in which crewmen did not survive, the available data are inadequate for ascertaining whether or not poor restraint under adverse G's was a factor in the loss of the aircraft or its crew. However, the few cases in which the contributory effect of adverse G's are documented suggest that many of the unwitnessed losses may have been influenced by in-flight accelerative forces for which the restraint systems could not compensate.

18. There is suggestive evidence in a number of accidents that, once the aircraft departed controlled flight, the pilot was unable to apply corrective action as a result of "hanging in his straps" due to negative G's. A survey of MOR's for the calendar period 1969 through 1976 suggests that inadequate restraint possibly contributed to the loss of 16 aircraft (table IV). The following excerpts taken from the MOR narratives are presented in support of this statement. Additional excerpts are presented in appendix L.

a. "A student pilot in a T-2 aircraft induced departure while performing a Cuban Eight. Student was "hanging in his straps" because he had not properly tightened his lap belt and was not able to apply proper control inputs to right the aircraft. The loose lap belt prevented the pilot from effectively controlling the aircraft while it was inverted."

b. "Pilot making a scissor roll during an ACM, this A-4 aircraft departed controlled flight and entered a violent inverted spin. The pilot's helmet was cracked as his head was thrown about the cockpit. He sustained various bruises as his body was forced upward against the left side of the canopy. The pilot's dazed/confused condition resulted in a loss of time at altitude, coupled with an inability to readily read his instruments and reach his controls due to the violent spinning, virtually eliminated any chance of recovery by 10,000 ft, so he ejected."

c. "During a routine flight, this F-4 aircraft, without any prior warning, pitched violently upward. The high degree of positive vertical G force caused the pilot to be bent over so that his head was approximately 1 in. above his knees. He became totally incapacitated, i.e., unable to use his controls to try and correct the situation and was unable to initiate ejection sequence. RIO had to initiate ejection."

d. "Prior to takeoff for an ACM, pilot of this A-7 aircraft was noted to have a slight difficulty in tightening the lap belt on the left side but felt it was satisfactory. During the ACM, the aircraft departed controlled flight and entered an inverted spin. Because of the loose lap belt, the pilot was pushed up and away from the seat. Unable to get proper control inputs because of being pinned against the canopy and passing through 10,000 ft, the pilot elected to eject."

e. "During an ACM flight, this F-8 aircraft suddently experienced a departure from controlled flight. Lateral G forces pinned the pilot against the right side of the canopy and extremely violent buffeting caused his head to repeatedly bang the side of the canopy. Dazed and being unable to read instruments or reach controls, the pilot ejected."

Table IV

Inadequate Restraint Possibly Contributed to Loss of Aircraft

| Aircraft Type | Ratio | % |
|---|---|---|
| A-4 | 4/177 | 2.3 |
| A-7 | 2/136 | 1.5 |
| A-6 | 0/51 | 0.0 |
| F-4 | 1/157 | 0.6 |
| F-8 | 3/79 | 3.8 |
| F-9 | 1/16 | 6.3 |
| F-14 | 1/9 | 11.1 |
| A-5 | 0/16 | 0.0 |
| T-2 | 4/28 | 14.3 |
| Total | 16/669 | 2.4 |

19. There is no doubt that the loss of some of the aircraft described above would not have been prevented even with adequate restraint. There is also no doubt that in some of these accidents the pilot's failure to properly strap into the seat did contribute (either directly or indirectly) to his inability to control the aircraft, to his egress difficulties, and/or to the injuries sustained due to poor body position and ejection forces. However, results obtained during the laboratory investigation suggest that in many cases the restraint problems described here might have occurred despite diligent efforts to properly strap in, which further suggests restraint system design inadequacies. Inadequate restraint, particularly inadequate negative G restraint, has been and continues to be a major factor in degrading the ability of the pilot to apply effective corrective action under uncontrolled flight conditions and also in the inability of the aircrew to eject or to survive aircraft ground impact. Inadequate restraint has resulted in the loss of aircraft that might have been saved and in the fatalities of aircrew who might otherwise have survived.

20. The data presented heretofore appear to give credence to the idea that aircrewmen do not wish to have an active restraint system (i.e., they wish to have a system which interferes less with their in-flight duties). This expresses the need for crew mobility, fatigue reduction, and decreased nuisance associated with active restraints. This idea, however, is a contradiction of documented needs for takeoff and landing restraint, crash/impact forces restraint, ejection restraint, and parachute harnessing. It is also inconsistent with the documented need for in-flight

restraint against G forces associated with turbulence, air combat maneuvers, and departure from controlled flight. The aviator's desire for a less active restraint and the documented need for this type of restraint leads to a dichotomous view of restraint requirements:

a. A need for minimum interference/nuisance during certain phases of flight.

b. Instantly available restraint during all phases of flight.

21. Current restraint systems used in Naval aircraft consist of:

a. A lap belt which must be tightened physically and which rides up over the pelvis or slips during negative G flight resulting in considerable off-seat displacement.

b. A manual locking device to restrain the upper torso which, when unlocked, maintains some residual resistance or drag to forward torso movement caused by the shoulder straps and strap take-up mechanism.

c. An automatic locking device at the inertia reel, activated by G loads/rate of payout of the shoulder straps, but which is ineffective at slow onset of acceleration and permits excessive forward movement of crew torsos during some phases of uncontrolled flight.

d. An automatic retraction feature activated only during ejection.

22. Additional features or desired changes in existing features of current restraint systems which would be desirable could include (but not be limited to):

a. A means to prevent the lap belt from riding up over the pelvis, keeping it properly positioned over the pelvic girdle.

b. The ability to automatically retract the aircrewman's entire torso (including the buttocks against the seat pan) repeatedly without manual resetting of the system. This retraction feature should be sensitive to both G loads and off-seat displacement and should be available at the pilot's option.

c. The capability to eliminate, or set, the drag force acting on the aircrew through the shoulder straps without loss of automatic inertia reel locking or retraction features. This capability could allow the aircrewman to select the range of G forces at which the system functions.

d. A provision for adequate lateral restraint.

23. The fact that the aircrewman must suit up for flight and perform functions prior to manning aircraft presents two environments for considerations: exocraft and endocraft. In the exocraft environment, his equipment must allow sufficient freedom of motion to permit walking, performing aircraft inspections, and mounting and dismounting the aircraft. It must also be comfortable enough in the ready room to minimize distraction from preflight briefings. Further, following

emergency escape, the restraint equipment should not impede the crewman's survival or enemy evasion efforts. In the endocraft environment, the equipment must provide effective restraint and to serve adequately as a parachute harness. If the MA-2 restraint garment is properly fitted and adjusted to provide the best possible service as a restraint and parachute harness, it is so tight that the aircrewman is in constant discomfort. Thus his needs for equipment which allow unrestricted mobility during preflight, aircraft ingress and egress, and ready room briefings cannot be met when the MA-2 harness is adjusted to provide optimal endocraft service. It has been suggested by personnel contacted by this investigator that if the MA-2 is left loosely adjusted to accommodate out-of-cockpit functions, cockpit geometry and aircrew anthropometry create difficulties in adjusting the harness fit, resulting in less than optimal harness performance (particularly as a parachute harness). Investigation of this problem did not support these findings. No difficulty was encountered in properly adjusting the MA-2 to the individual, using the chest strap, while seated in a variety of fighter and attack aircraft, using a subject of 77th percentile seated height. Nevertheless, a restraint system should be designed to give exocraft mobility as well as good endocraft restraint. A requirement for an acceptable system should specify ready transition from a walk-around configuration to optimal in-cockpit restraint, without requiring expenditure of time adjusting the restraint garment in the cockpit.

24. Seat slap was specifically indicated in the MOR's as a cause of torso injuries in 13 of the total 920 ejections (table III). This statistic might be misleading because there were 93 ejections in which "forces of ejection" were reported as the cause of torso injury. Poor body position at the moment of ejection is perhaps another indicator of ineffective restraint. As can be seen from table III, 85 ejectees were reported to have sustained upper torso/spinal injuries due to poor body position. Examination of available data was not amenable to a breakdown into areas of poor restraint, yet it appears that many aviators are receiving spinal or torso injuries as a result of poor seat/man contact which could (in some cases) be attributed to inadequate restraint at the moment of ejection.

25. Thirty-five percent of the ejectees (318 of 920) utilized seats with unpowered inertia reels (no automatic haul-back of torso) and accounted for 49% (42 cases) of the injuries due to poor body position. Almost one out of every four aircrewmen who ejected with unpowered inertia reels reported some form of injury. Only one out of six aircrewmen reported the same type of injuries when using seats equipped with power inertia reels (automatic haul-back of torso). Twenty percent of these injuries were classified as major. Minor injuries (such as muscle strain, contusions, or soft tissue pain) are to be expected as a common consequence of ejecting from an uncontrolled aircraft. These types of injuries are not of primary concern. The major injuries (such as spinal damage and bone wounds), which can and occasionally do lead to permanent disability and grounding of experienced aviators, are those injuries which demand attention.

26. The reported incidence of control and emergency egress difficulties in aircraft utilizing the Martin-Baker, Douglas Escape Package (ESCAPAC), and North American ejection seats are shown in tables V, VI, and VII, respectively. Similar data on reported egress injuries are shown in tables VIII, IX, and X. Table IV shows the rate of occurrence with which inadequate restraint possibly contributed to the

loss of the aircraft. When placed in rank order (table XI) and categorized into least, average, and most reported problems (table XII), the data indicate that among current, large-inventory, U.S. Navy aircraft, the greatest overall problems are being experienced by aircrewmen in the F-14 (in 83% of all F-14 ejections) and in the T-2 (in 47% of all T-2 ejections); the least problems are being experienced by aircrewmen in the F-4 (in 17% of all F-4 ejections). Among aircraft no longer in use or used only on a limited basis, the F-9 appears to be the focus of the largest number of problems (in 64% of all F-9 ejections), and the A-5 has the least reported number of problems (in 9% of all A-5 ejections). The scope of this effort did not permit a more detailed analysis to determine whether or not the problems reported here are associated with specific seat types. Until an in-depth comparative investigation is conducted of restraint system installation, aircraft mission profiles, aircrew anthropometric compatibility, and hours of flight time, as well as revised regulations for reporting restraint problems (also an increase in sample population, at least for the F-14 and T-2 aircraft), the "success" or "failure" of aircraft restraint systems, such as indicated by these statistics, remains subject to speculation and controversy.

Table V

Percent Ejectees Utilizing Martin-Baker Ejection Seats Who Experience Difficulty Controlling Aircraft, Initiating Ejection, and/or Seat Slap Because of Inadequate Restraint

| Aircraft Type | Seat Type | No. of Ejectees Reporting One or More Restraint Problem (1)* | | Difficulty Applying Corrective Action (2)* | | Difficulty/Unable to Initiate Ejection (3)* | | Seat Slap (4)* | | Total by Seat Type | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Martin-Baker | Ratio | % | Ratio | % | Ratio | % | Ratio | % | Ratio | % |
| A-6 | GRUEA7 | 0/10 | 0.0 | 0/10 | 0.0 | 0/10 | 0.0 | 0/10 | 0.0 | 0/10 | 0.0 |
| | GRU7 | 0/23 | 0.0 | 0/23 | 0.0 | 0/23 | 0.0 | 0/23 | 0.0 | 0/23 | 0.0 |
| | GRU5** | 7/73 | 9.6 | 0/73 | 0.0 | 7/73 | 9.6 | 0/73 | 0.0 | 14/73 | 19.2 |
| | Total by Aircraft | 7/106 | 6.6 | 0/106 | 0.0 | 7/106 | 6.6 | 0/106 | 0.0 | 7/106 | 6.6 |
| F-14 | GRU7A | 7/18 | 38.9 | 1/18 | 5.6 | 6/18 | 33.3 | 1/18 | 5.6 | 15/18 | 83.3 |
| F-4 | H7A | 0/12 | 0.0 | 0/12 | 0.0 | 0/12 | 0.0 | 0/12 | 0.0 | 0/12 | 0.0 |
| | H5A | 10/259 | 3.9 | 1/259 | 0.4 | 4/259 | 1.5 | 6/259 | 2.3 | 11/259 | 4.1 |
| | Total by Aircraft | 10/271 | 3.7 | 1/271 | 0.4 | 4/271 | 1.5 | 6/271 | 2.3 | 11/271 | 4.1 |
| F-8 | F5A** | 3/14 | 21.4 | 1/14 | 7.1 | 2/14 | 14.3 | 0/14 | 0.0 | 6/14 | 42.9 |
| | F7A | 4/65 | 6.2 | 2/65 | 3.1 | 2/65 | 3.1 | 0/65 | 0.0 | 8/65 | 12.3 |
| | Total by Aircraft | 7/79 | 8.9 | 3/79 | 3.8 | 4/79 | 5.1 | 0/79 | 0.0 | 14/79 | 17.7 |
| F-9 | Z5A** | 1/5 | 20.0 | 1/5 | 20.0 | 1/5 | 20.0 | 0/5 | 0.0 | 3/5 | 60.0 |
| | A7A | 2/7 | 28.6 | 0/7 | 0.0 | 2/7 | 28.6 | 0/7 | 0.0 | 4/7 | 57.1 |
| | A5A** | 2/16 | 12.5 | 0/16 | 0.0 | 1/16 | 6.3 | 1/16 | 6.3 | 4/16 | 25.0 |
| | Total by Aircraft | 5/28 | 17.9 | 1/28 | 3.6 | 4/28 | 14.3 | 1/28 | 3.6 | 11/28 | 39.3 |

NOTE: Aircrewman could appear in more than one category.
*Numbers in parentheses are categorized in table XI.
**Indicates unpowered inertia reels.

Table VI

Percent Ejectees Utilizing Douglas Escapac Ejection Seats Who Experienced Difficulty Controlling Aircraft, Initiating Ejection, and/or Seat Slap Because of Inadequate Restraint

| Aircraft Type | Seat Type | No. of Ejectees Reporting One or More Restraint Problem (1)* | | Difficulty Applying Corrective Action (2)* | | Difficulty/Unable to Initiate Ejection (3)* | | Seat Slap (4)* | | Total by Seat Type | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Escapac | Ratio | % | Ratio | % | Ratio | % | Ratio | % | Ratio | % |
| A-4 | 1** | 2/7 | 28.6 | 0/7 | 0.0 | 2/7 | 28.6 | 0/7 | 0.0 | 4/7 | 56.1 |
| | IC3 | 7/103 | 6.8 | 2/103 | 1.9 | 3/103 | 2.9 | 2/103 | 1.9 | 14/103 | 13.6 |
| | IA1** | 2/77 | 2.6 | 1/77 | 1.3 | 2/77 | 2.6 | 0/77 | 0.0 | 5/77 | 6.5 |
| | IF3 | 3/12 | 25.0 | 0/12 | 0.0 | 2/12 | 16.7 | 1/12 | 8.3 | 6/12 | 50.0 |
| | IG3 | 3/6 | 50.0 | 1/6 | 16.7 | 3/6 | 50.0 | 0/6 | 0.0 | 7/6 | 116.7 |
| | Total by Aircraft | 17/205 | 8.3 | 4/205 | 2.0 | 12/205 | 5.9 | 3/205 | 1.5 | 36/205 | 17.6 |
| A-7 | IC2A** | 8/126 | 6.4 | 2/126 | 1.5 | 7/126 | 5.5 | 1/126 | 0.8 | 18/126 | 14.3 |
| | IG2 | 1/10 | 10.0 | 0/10 | 0.0 | 1/10 | 10.0 | 0/10 | 0.0 | 2/10 | 20.0 |
| | Total by Aircraft | 9/136 | 6.6 | 2/136 | 1.5 | 8/136 | 5.9 | 1/136 | 0.7 | 20/136 | 14.7 |

NOTE: Aircrewman could appear in more than one category.
*Numbers in parentheses are categorized in table XI.
**Indicates unpowered inertia reels.

Table VII

Percent Ejectees Utilizing North American Ejection Seats Who Experienced Difficulty Controlling Aircraft, Initiating Ejection, and/or Seat Slap Because of Inadequate Restraint

| Aircraft Type | Seat Type | No. of Ejectees Reporting One or More Restraint Problem (1)* | | Difficulty Applying Corrective Action (2)* | | Difficulty/Unable to Initiate Ejection (3)* | | Seat Slap (4)* | | Total by Seat Type | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | North American | Ratio | % | Ratio | % | Ratio | % | Ratio | % | Ratio | % |
| T-2 | LS1 | 5/45 | 11.1 | 4/45 | 8.9 | 4/45 | 8.9 | 1/45 | 2.2 | 14/45 | 31.1 |
| A-5 | HS1A | 0/5 | 0.0 | 0/5 | 0.0 | 0/5 | 0.0 | 0/5 | 0.0 | 0/5 | 0.0 |
| | HS1 | 0/27 | 0.0 | 0/27 | 0.0 | 0/27 | 0.0 | 0/27 | 0.0 | 0/27 | 0.0 |
| | Total by Aircraft | 0/32 | 0.0 | 0/32 | 0.0 | 0/32 | 0.0 | 0/32 | 0.0 | 0/32 | 0.0 |
| Grand Total Tables V, VI, and VII | | 67/920 | 7.3 | 16/920 | 1.7 | 49/920 | 5.3 | 13/920 | 1/4 | 145/920 | 15.8 |

NOTE: Aircrewman could appear in more than one category.
*Numbers in parentheses are categorized in table XI.

Table VIII

Percent Ejectees Utilizing Martin-Baker Ejection Seats Who Received Injuries Due to Poor Body Position or Ejection Forces

| Aircraft Type | Seat Type | Injuries Due to Ejection Forces (5)* | | Injuries Due to Poor Body Position (6)* | | Totals by Seat Type | |
|---|---|---|---|---|---|---|---|
| | Martin-Baker | Ratio | % | Ratio | % | Ratio | % |
| A-6 | GRUEA7 | 0/10 | 0.0 | 0/10 | 0.0 | 0/10 | 0.0 |
| | GRU7 | 0/23 | 0.0 | 0/23 | 0.0 | 0/23 | 0.0 |
| | GRU5** | 11/73 | 15.1 | 19/73 | 26.0 | 30/73 | 41.1 |
| | Total by Aircraft | 11/106 | 10.4 | 19/106 | 17.9 | 30/106 | 28.3 |
| F-14 | GRU7A | 5/18 | 27.8 | 2/18 | 11.1 | 7/18 | 38.9 |
| F-4 | H7A | 1/12 | 8.3 | 1/12 | 8.3 | 2/12 | 16.7 |
| | H5A | 21/259 | 8.1 | 13/259 | 5.0 | 34/259 | 13.1 |
| | Total by Aircraft | 22/271 | 8.1 | 14/271 | 5.2 | 36/271 | 13.3 |
| F-8 | F5A** | 1/14 | 7.1 | 2/14 | 14.3 | 3/14 | 21.4 |
| | F7A | 7/65 | 10.8 | 4/65 | 6.2 | 11/65 | 16.9 |
| | Total by Aircraft | 8/79 | 10.1 | 6/79 | 7.6 | 14/79 | 17.7 |
| F-9 | Z5A** | 0/5 | 0.0 | 0/5 | 0.0 | 0/5 | 0.0 |
| | A7A | 1/7 | 14.3 | 1/7 | 14.3 | 2/7 | 28.6 |
| | A5A** | 3/16 | 18.8 | 7/16 | 43.8 | 10/16 | 62.3 |
| | Total by Aircraft | 4/28 | 14.3 | 8/28 | 28.6 | 12/28 | 42.9 |

*Numbers in parentheses are categorized in table XI.
**Indicates unpowered inertia reels.

Table IX

Percent Ejectees Utilizing Douglas Escapac Ejection Seats Who Received Injuries Due to Poor Body Position or Ejection Forces

| Aircraft Type | Seat Type | Injuries Due to Ejection Forces (5)* | | Injuries Due to Poor Body Position (6)* | | Totals by Seat Type | |
|---|---|---|---|---|---|---|---|
| | Escapac | Ratio | % | Ratio | % | Ratio | % |
| A-4 | 1** | 1/7 | 14.3 | 0/7 | 0.0 | 1/7 | 14.3 |
| | IC3 | 14/103 | 13.6 | 10/103 | 9.7 | 24/103 | 23.3 |
| | IA1** | 3/77 | 3.9 | 3/77 | 3.9 | 6/77 | 7.8 |
| | IF3 | 1/12 | 8.3 | 1/12 | 8.3 | 2/12 | 16.7 |
| | IG3 | 1/6 | 16.7 | 3/6 | 50.0 | 4/6 | 66.7 |
| | Total by Aircraft | 20/205 | 9.8 | 17/205 | 8.3 | 37/205 | 18.1 |
| A-7 | IC2A** | 15/126 | 11.9 | 11/126 | 8.7 | 26/126 | 20.6 |
| | IG2 | 0/10 | 0.0 | 1/10 | 10.0 | 1/10 | 10.0 |
| | Total by Aircraft | 15/136 | 11.0 | 12/136 | 8.8 | 27/136 | 19.9 |

*Numbers in parentheses are categorized in table XI.
**Indicates unpowered inertia reels.

Table X

Percent Ejectees Utilizing North American Ejection Seats Who Received Injuries Due to Poor Body Position or Ejection Forces

| Aircraft Type | Seat Type | Injuries Due to Ejection Forces (5)* | | Injuries Due to Poor Body Position (6)* | | Totals by Seat Type | |
|---|---|---|---|---|---|---|---|
| | North American | Ratio | % | Ratio | % | Ratio | % |
| T-2 | LS1 | 6/45 | 13.3 | 6/45 | 13.3 | 12/45 | 26.7 |
| A-5 | HS1A | 0/5 | 0.0 | 0/5 | 0.0 | 0/5 | 0.0 |
| | HS1 | 2/27 | 7.4 | 1/27 | 3.7 | 3/27 | 11.1 |
| | Total by Aircraft | 2/32 | 6.3 | 1/32 | 3.1 | 3/32 | 9.4 |
| Grand Total Tables VIII, IX, and X | | 93/920 | 10.1 | 85/920 | 9.2 | 178/920 | 19.4 |

*Numbers in parentheses are categorized in table XI.

Table XI

Ranking Table

| Aircraft Type | Categories from Tables V, VI, VII, VII, IX, and X | | | | | | Total Score | Final Rank |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | | |
| A-5 | 1.0 | 1.5 | 1.0 | 2.0 | 1.0 | 1.0 | 7.5 | 1 |
| F-4 | 2.0 | 3.0 | 2.0 | 7.0 | 2.0 | 2.0 | 18.0 | 2 |
| F-8 | 6.0 | 7.0 | 3.0 | 2.0 | 4.0 | 3.0 | 25.0 | 3 |
| A-6 | 3.5 | 1.5 | 6.0 | 2.0 | 5.0 | 8.0 | 26.0 | 4 |
| A-4 | 5.0 | 5.0 | 4.5 | 5.0 | 3.0 | 4.0 | 26.5 | 5 |
| A-7 | 3.5 | 4.0 | 4.5 | 4.0 | 6.0 | 5.0 | 27.0 | 6 |
| T-2 | 7.0 | 9.0 | 7.0 | 6.0 | 7.0 | 7.0 | 42.0 | 7 |
| F-9 | 8.0 | 6.0 | 8.0 | 8.0 | 8.0 | 9.0 | 47.0 | 8 |
| F-14 | 9.0 | 8.0 | 9.0 | 9.0 | 9.0 | 6.0 | 50.0 | 9 |

NOTE: Rank order based on the percent of problems in each category for each aircraft. Categories ranked in ascending order; i.e., from best to worst.

Table XII

Grouping of Aircraft into Least, Average, Most Problems Reported

| | | % Ejectees Reporting Problems | | % of Total Reported Problems | | % of Total Ejection | |
|---|---|---|---|---|---|---|---|
| Category | Aircraft Type | Ratio | % | Ratio | % | Ratio | % |
| Least Reported Problems | A-5<br>F-4 | 49/303 | 16.0 | 49/256 | 19.0 | 303/920 | 33.0 |
| Average Reported Problems | A-4<br>A-7<br>A-6<br>F-8 | 148/526 | 28.0 | 152/256 | 60.0 | 526/920 | 57.0 |
| Most Reported Problems | F-14<br>F-9<br>T-2 | 48/ 91 | 53.0 | 54/256 | 21.0 | 91/920 | 10.0 |

UNSATISFACTORY REPORTS

27. Investigation of the aircrew restraint system included a review of the UR's covering a 9-year period from 1968 to 1976. The purpose of this review was to identify the components and systems failures/malfunctions that impair personnel restraint during aircraft flight operations or ejectee safety during an escape attempt. The personnel restraint system is considered to include, in addition to the MA-2 torso harness, the inertia reel; parachute risers, releases, and adapters; lap belt anchor straps, releases, and adapters; and the inertia reel lock manual control mechanism. The review disclosed 79 reports of deficiencies which had the potential for adversely affecting personnel restraint during aircraft flight operations and/or aircrew safety during an attempted escape.

28. Fifty-eight (73.4%) of the reported deficiencies addressed the inertia reel. In addition to degrading personnel restraint during flight operations, these deficiencies increase aircraft maintenance and could result in degraded escape system performance during an aircraft emergency (table XIII). Three of the remaining 18 UR's (3.8% of the total) specifically addressed the MA-2 torso harness. The chest strap was improperly routed, machine stitching was absent from the main sling, and the lap belt separated from the harness during and after ejection.

## Table XIII

## Aircrew Restraint System Unsatisfactory Reports

| Mechanism | Function | Total | Specific Deficiency | Cause(s) | Effect |
|---|---|---|---|---|---|
| MA-2 Torso Harness | Provides the interface between crew members and parachute/survival kit assembly. | 3 | ·Machine stitching missing from main sling.<br>·Improperly routed chest strap.<br>·Lap belt separated from MA-2 during ejection. | ·Improper maintenance procedures. | ·Degrade structural integrity of torso harness.<br>·Potential personnel injury during ejection. |
| Survival kit attachments | Provides link between ejection seat and aircrew member's lap belt. | 2 | ·Lap belt attachment fitting broken.<br>·Kit difficult to remove *from ejection seat.* | ·Improper installation procedures.<br>·Improper installation procedures - potential Murphy. | ·Preclude tightening lap belts - potential personnel injury during landing/airborne emergency.<br>·Impede seat/man separation failure during ejection. |
| Lap belt assembly | Provides means of attaching the torso harness to the survival kit/ejection seat. | 13 | ·Loose retaining screws in release mechanism.<br>·Inverted lap belt release.<br>·Keeper restricts lap belt adjustment.<br>·Jammed release mechanism.<br>·Broken lap belt attachment fitting. | ·Improper installation procedures.<br>·Worn Teflon locking pellets.<br>·Interference with LPA.<br>·Maintenance error.<br>·Improper mating of fittings. | ·Degrades personnel restraint during flight operations and emergency escape.<br>·Increases aircraft maintenance requirements. |
| Inertia reel manual locking system | Provides a means of locking the inertia reel prior to takeoff and landing. | 12 | ·Failure to lock/unlock. | ·Binding linkage.<br>·Broken spring. | ·Degrades restraint system performance.<br>·Increases aircraft maintenance. |
| Inertia reel buffer system | Provides means of attaching the torso harness to the survival kit/ejection seat. | 6 | ·Oil contamination. | ·Failed 0-ring.<br>·Improper installation procedures.<br>·Defective gas generator piston. | ·Degrades restraint system performance.<br>·Increases aircraft maintenance. |
| Inertia reel housing | | 3 | ·Improper safety locking procedure/missing bolts. | ·Maintenance error. | ·Potential inadvertent unlocking of reel. |
| Inertia reel strap assembly | | 6 | ·Inadvertent strap release.<br>·Jammed strap/lugs. | ·Insufficient length of disconnect cable.<br>·Reversed installation of release plunger.<br>·Lugs oversized - yoke assembly too small. | ·Degrades personnel restraint.<br>·Impairs seat/man separation. |
| Inertia reel retraction system | Provides shoulder restraint during aircraft maneuvers, landings, and ejections. | 20 | ·Failure of straps to retract. | ·Disconnect strap retainer.<br>·Improper finish of mating parts.<br>·Uneven strap wear.<br>·Uneven strap retraction.<br>·Excessively thick webbing.<br>·Strap backlash.<br>·Broken reel guard.<br>·Collapsed compression spring.<br>·Misassembled reel. | ·Degradation of aircrew restraint during flight operations/emergency escape.<br>·Increased aircraft maintenance.<br>·Increased logistic requirements. |
| *Inertia reel automatic locking system* | Provides shoulder restraint during aircraft maneuvers, landings, and ejections. | 11 | ·Failure to lock automatically. | ·Weak spring pawl out of adjustment.<br>·Inadequate operating rod clearance.<br>·Binding of internal parts.<br>·Broken cover. | ·Degrades personnel restraint during flight operations.<br>·Increases aircraft maintenance requirements. |

29. The maximum number of UR's submitted against the examined aircrew restraint systems in any one year was 16, in 1969 and again in 1976 (figure 2). The majority of the 16 UR's submitted in each of these years cite the "inertia reel strap failure to retract" as the malfunction.

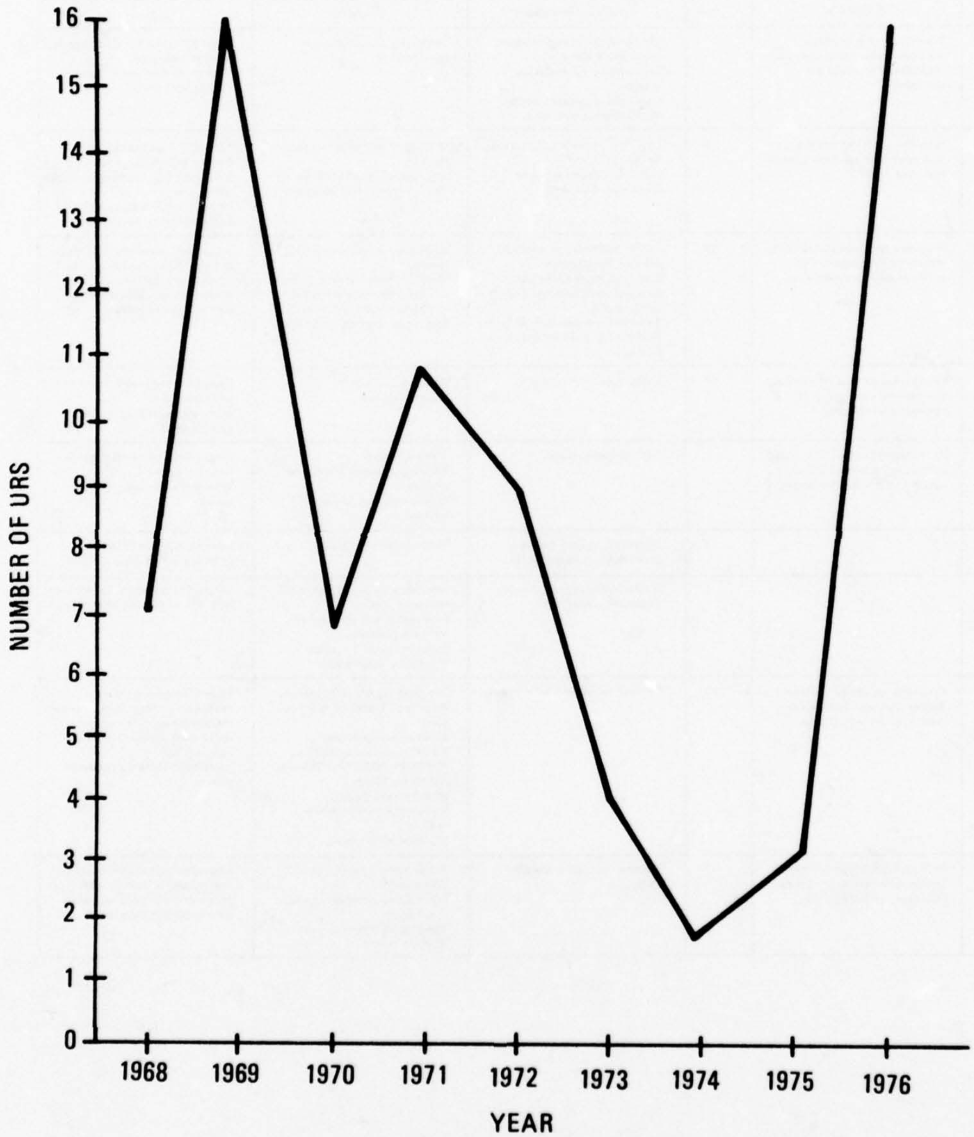



Figure 2
Frequency of Restraint System
Deficiencies Reported

30. The purpose of the UR system is to provide a standard system for reporting deficient reworked or newly procured material that causes situations which require prompt attention and corrective action (reference 6). Frequently, however, corrective action which is readily implemented (i.e., adjusting linkage, replacing straps) is accomplished without submitting a UR. In addition, as users become familiar with the equipment, they learn to compensate for (live with) design deficiencies and commonly occurring nuisances. Maintenance personnel learn by experience to anticipate problems and take corrective action before a UR is required. Occasionally, UR's are erroneously submitted, citing nonexistent deficiencies. Considering the aforementioned fallacies in the UR system and the relatively small sample of restraint system UR's available, it would be imprudent to draw specific conclusions based on the results of this review. This review does, however, indicate that difficulties, sufficient to cause preparation of UR's, are being experienced with the inertia reel shoulder retraction and locking system (49 UR's or 62% of the total). Breakdowns of the various categories of UR's concerning restraint system deficiencies, their frequency of occurrence, and a comparative breakdown of the MOR's are shown in figure 3. It is recommended that future redesign efforts of the torso restraint system include provisions to optimize full retraction of the shoulder straps during normal flight operations and minimize the potential for strap/mechanism binding or failure to retract fully.

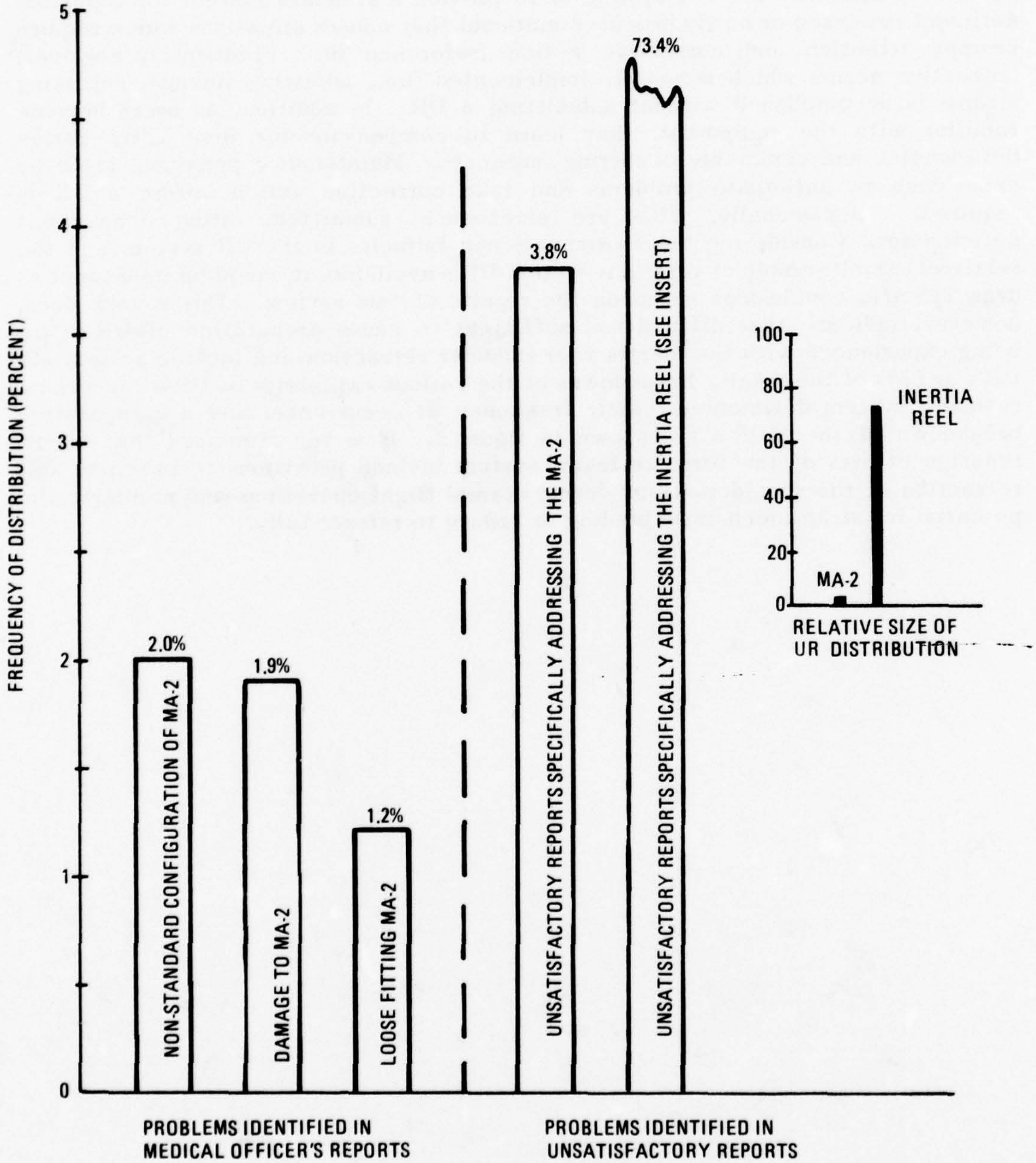



Figure 3
Relative Frequency of Reported Problems: MOR Versus UR

LABORATORY STUDY OF BODY MOTION IN RESTRAINT

31. The purpose of this laboratory study was to:

a. Define specific components of body shift when in restraints typical of those used in U.S. Navy aircraft during periods of negative gravitational influence (-Gz).

b. Analyze this shift, examining the source or sources of the shift.

c. Relate body shift to aircraft control difficulties under -Gz.

d. Determine the adequacy or inadequacy of the MA-2 Integrated Torso Harness in restraining a body subjected to -Gz.

32. Five male human volunteer subjects with varying anthropometry (table I of appendix H) were utilized in the study. Each of the subjects was used in six different tests, each consisting of five backward mode rotations to an inverted position (+Gz through +Gx to -Gz) per test. In addition, two subjects were used in restraint tests types 1 and 4 using forward mode rotations (+Gz through -Gx to -Gz). Military transfer accounted for subject attrition and nonavailability of the same subjects for complete forward rotation tests. A detailed description of test equipment and test protocol is given in appendices G and H, respectively.

33. The experimental restraining devices used in the study (appendix H) SHOULD NOT be construed as developmental prototypes of personnel restraints for use in aircraft. They were specifically-designed restraints for enhancing accomplishment of specific investigations for this study ONLY. Many trade-offs which would be unacceptable for long-term crew restraint were incorporated into these test restraint system configurations to achieve specific test objectives.

34. In order to remain with the scope of this task, the tests were conducted utilizing only the Douglas ESCAPAC IC-3 seat fitted with an RSSK-8A rigid seat pan survival kit and an NES-10 personnel parachute. This configuration essentially eliminated motion of the seat pan within the seat frame (seat pan "wobble"). It should be noted that the test results indicate the composition of factors contributing to poor or inadequate restraint system performance, as well as their relative magnitude under -1 Gz. It is doubtful that major changes in these contributions would result from conducting similar investigations using other U.S. Navy inventory ejection seats, since:

a. All use the same torso garment.

b. The MOR data indicate that restraint problems occur throughout the inventory of U.S. Navy aircraft and, therefore, ejection seats.

35. Raw data (appendix M) were obtained in the form of polar coordinates with a 2.25-in. (5.72-cm) offset at the sighting point (figure 4 of appendix G). This data were then converted to two-dimensional X and Y coordinates. The measurements taken for each subject described a set of five pairs of X and Y coordinates per target point per test. The median values of the X and Y coordinates for each test were chosen and the resultant computed (appendix N). The formulas used for data conversion are shown in appendix O. The use of median values instead of mean values* provided a better representation of the distribution because it eliminated occasional deviant values. The median data were subjected to a Two-Way Analysis of Variance. Tukey's Honestly Significant Difference (HSD) Test (reference 7) was used to evaluate the significance of differences between adjacent means.

Components of Body Motion

36. A schematic representation of the components of body motion measured during this study is shown in figure 4. Average measurements are summarized in table XIV.

a. Head Displacement (figure 5): When subjected to -Gz, the head moved away from the plane of reference (seat pan). Head displacements for experimental restraint configurations 1 and 2 were not significantly different from one another, but each was significantly higher than restraint configurations 3, 4, 5, and 6 ($P<.05$**). Head displacement for restraint configurations 3, 4, 5, and 6 were not significantly different from one another.

b. Off-Seat Displacement (figure 5): When subjected to -Gz, every subject lost physical contact with the seat pan, regardless of the type of experimental restraint configurations used. Off-seat displacement was significantly greater ($P<.05$) when using restraint configurations 1 and 2 than for the other restraint configuration used. The other restraint configurations (3, 4, 5, and 6) appeared to reduce this displacement by approximately 50%, except restraint configuration 5 which reduced the displacement by a lesser amount (approximately 35%).

c. Upper Torso Stretch: As can be seen in figure 5, displacement of the head exceeded off-seat displacement. The difference in motion between the head and off-seat displacement is attributable to the torso stretching between these two points. In every test run, this difference was greater than zero, ranging from 0.9 in. (2.29 cm) to 1.6 in. (4.06 cm). There was no significant difference between torso stretch measured with the MA-2 garment and that which occurred when using any of the experimental restraint configurations.

*Mean - the number obtained by summing each value of X, then dividing the sum by the total number of X entries. Median - the middle number in a series, or the number midway between the two middle numbers in a series (where N is an even number).

**$P<.05$ means that the probability of rejecting a null hypothesis when it is true is less than 5 times out of 100. A null hypothesis states that there are no significant differences between the observations.

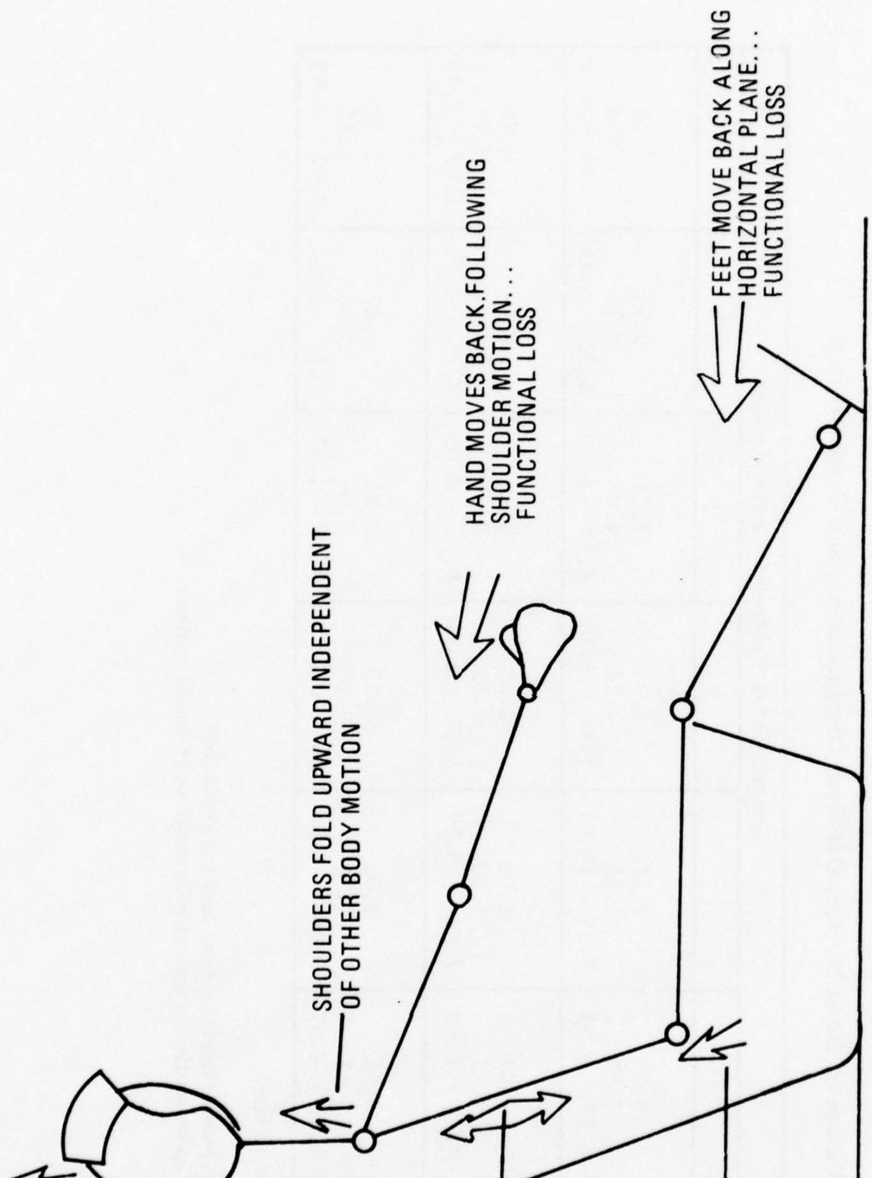



Figure 4
A Schematic Representation of the Components of
Body Motion Measured in this Study

Table XIV

Observed Values of Head Motion, Off-Seat Displacement, and Torso Stretch

| Parameters Measured | Experimental Restraint Configurations | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Head Displacement* | | | | | | |
| Mean | 8.89 | 7.87 | 5.33 | 5.08 | 5.33 | 5.08 |
| Standard Deviation (±) | 1.50 | 1.65 | 1.12 | 1.07 | 0.79 | 0.94 |
| Range | 6.35 - 9.91 | 6.35 - 10.41 | 3.81 - 6.10 | 4.32 - 6.10 | 4.32 - 6.35 | 3.81 - 6.10 |
| Off-Seat Displacement | | | | | | |
| Mean | 5.08 | 4.06 | 2.03 | 1.27 | 2.79 | 1.78 |
| Standard Deviation (±) | 1.27 | 1.40 | 0.58 | 0.56 | 0.64 | 0.76 |
| Range | 3.30 - 6.60 | 2.54 - 5.59 | 1.27 - 2.54 | 0.76 - 2.03 | 2.29 - 3.56 | 1.02 - 2.79 |
| Torso Stretch** | | | | | | |
| Mean | 3.56 | 4.06 | 3.30 | 3.81 | 2.29 | 3.30 |
| Standard Deviation (±) | 0.58 | 0.84 | 0.89 | 0.66 | 0.64 | 1.42 |
| Range | 3.05 - 4.57 | 3.05 - 5.33 | 2.29 - 4.32 | 3.05 - 4.57 | 1.27 - 3.30 | 1.02 - 4.83 |

All measurements in centimeters (cm).

* Head motion comprised of off-seat displacement and torso stretch
**Torso Stretch is calculated as head displacement minus off-seat displacement

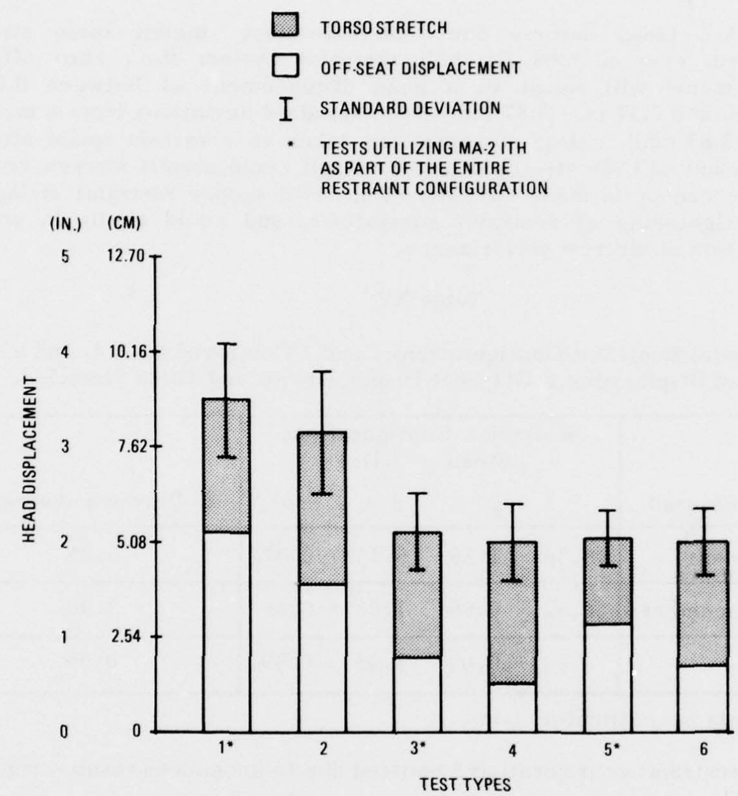



Figure 5
Average Head Displacement During -1 Gz

37. The off-seat displacement and torso stretch data for experimental restraint configuration 5 is an enigma. Since head displacement for this run appears to be comparable to other values of head motion, the significant increase in off-seat displacement of all subjects is highly suspect when compared to that obtained when using restraint configurations 3, 4, and 6. This restraint configuration causes the torso stretch to appear significantly reduced. None of the experimental restraint configurations employed should have changed torso stretch significantly. Consultation with the NAVAIR sponsor advised that the scope of this study could not allow for further examination of this interesting observation. With the elimination of experimental restraint configuration 5 (due to the anomalous behavior), head displacement, off-seat displacement, and upper torso stretch, as indicated in table XV, shows the following:

a. The present MA-2 lap belt subsystem, even when adjusted unnaturally tight, allows an average off-seat displacement of 1.8 in. (4.57 cm) under -1 Gz.

b. An average reduction of 1.28 in. (3.25 cm) was achieved in overall body movement by improving pelvic restraint.

c. The MA-2 torso harness does not effectively inhibit torso stretch. Therefore, even a good lap belt restraint system (i.e., zero off-seat displacement) will result in a head displacement of between 0.69 in. (1.75 cm) and 2.31 in. (5.87 cm) (three standard deviations from a mean of 1.5 in. (3.81 cm)), unless measures are taken to constrain spinal stretch. This amount of body stretch of and by itself could permit aircrew contact with the canopy in many aircraft, even with proper restraint sizing and proper tightening of restraint subsystems, and could result in serious degradation of aircrew performance.

Table XV

Experimental Restraint Configurations 1 and 2 Compared to 3, 4, and 6 for Head Displacement, Off-Seat Displacement, and Torso Stretch

| Parameters Measured | Restraint Configurations (Mean ± S.D.) 1 + 2 | 3 + 4 + 6* | Δ Between Averages |
|---|---|---|---|
| Head Displacement | 8.38 ± 1.55 | 5.13 ± 0.97 | 3.25 |
| Off-Seat Displacement | 4.57 ± 0.56 | 1.68 ± 0.66 | 2.90 |
| Torso Stretch | 3.81 ± 0.69 | 3.45 ± 0.99 | 0.36 |

All measurements in centimeters (cm).

*Experimental restraint configuration 5 omitted due to anomalous results reported in paragraph 32.

38. It is recommended that requirements for restraint of the torso be considered in two parts:

a. "Fixing" the buttocks of the aircrewman firmly to the seat pan.

b. Control of the degree of torso stretch.

It is further recommended that before design requirements to control stretch are formulated, a thorough investigation be performed, both through literary searches and active laboratory studies, to determine spinal stretch differentiation under various negative G loads. Such an investigation was not within the scope of this study.

39. Shoulder Displacement: In every subject, for every test, the shoulder displacement exceeded head movement. These results indicate that shoulder motion follows body motion; that is, for a given amount of torso stretch or off-seat displacement, an equivalent amount of motion can be anticipated at the shoulder joint, accompanied by an additional amount of motion within the shoulder itself (from 0.86 to 1.76 in. (2.3 to 4.6 cm), (table XVI and figure 6)). Shoulder motion was not significantly altered by the different experimental restraint configurations. While significant variation ($P<.05$) between subjects did occur, it could not be correlated to subject anthropometry and is considered to be a random variation.

| Parameters Measured | Experimental Restraint Configurations | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| **Shoulder Displacement** | | | | | | |
| Mean | 10.92 | 11.43 | 8.89 | 9.40 | 9.40 | 9.65 |
| Standard Deviation (±) | 1.09 | 2.79 | 3.05 | 2.51 | 2.39 | 1.83 |
| Range | 9.65 - 12.19 | 7.37 - 14.99 | 5.84 - 13.21 | 6.86 - 12.45 | 6.86 - 12.70 | 6.60 - 11.18 |
| **Loss of Effective Foot Reach** | | | | | | |
| Mean | 4.32 | 4.32 | 1.78 | 3.56 | 2.29 | 2.29 |
| Standard Deviation (±) | 0.86 | 0.99 | 1.14 | 1.12 | 0.79 | 0.74 |
| Range | 2.79 - 5.08 | 2.79 - 5.33 | 1.27 - 3.81 | 2.29 - 5.59 | 1.52 - 3.56 | 1.52 - 3.56 |
| **Loss of Effective Hand Reach** | | | | | | |
| Mean | 7.62 | 7.11 | 3.81 | 4.32 | 4.57 | 4.32 |
| Standard Deviation (±) | 2.34 | 2.79 | 1.96 | 1.68 | 1.91 | 2.79 |
| Range | 4.57 - 10.92 | 3.81 - 10.41 | 2.03 - 7.11 | 1.78 - 5.84 | 3.05 - 6.86 | 1.78 - 8.64 |

All measurements in centimeters (cm).

Table XVI

Observed Values of Shoulder Displacement, Loss of Effective Foot Reach, and Loss of Effective Hand Reach

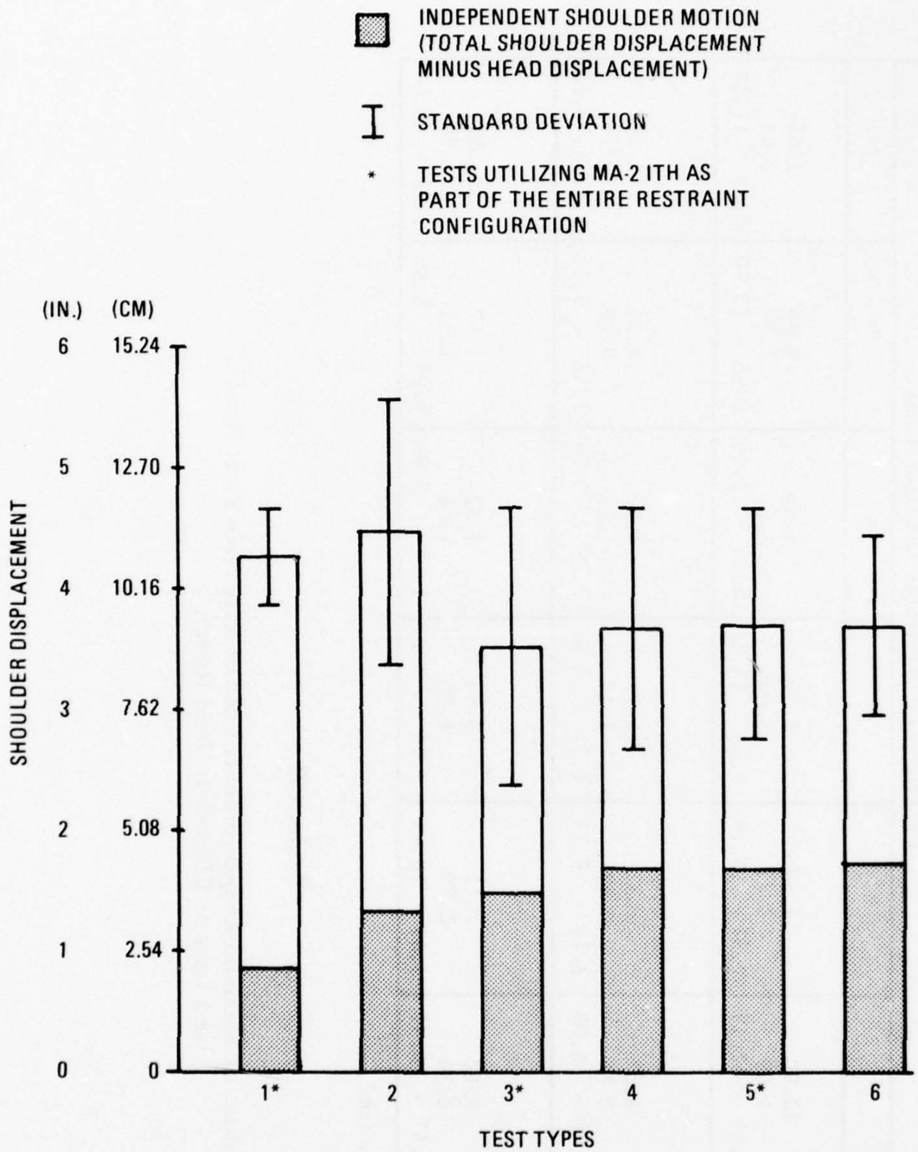



Figure 6
Average Shoulder Displacement during -1 Gz

40. Foot Displacement: When subjects were inverted from +Gz to -Gz, their feet moved away from the plane of reference (simulated rudder pedals), reducing effective functional foot reach. Loss of effective foot reach in experimental restraint configurations 1 and 2 was significantly greater ($P<.05$) than restraint configurations 3, 5, and 6 (figure 7 and table XVI). There was no significant difference in effective foot reach when comparing runs 3, 4, 5, and 6 to each other. The significantly greater loss of effective foot reach when using the MA-2 (restraint configuration 1) could result in less than optimal rudder control, or in erratic rudder control inputs, and could present the pilot with a psychologically distressing situation (which might further aggravate the control problem).

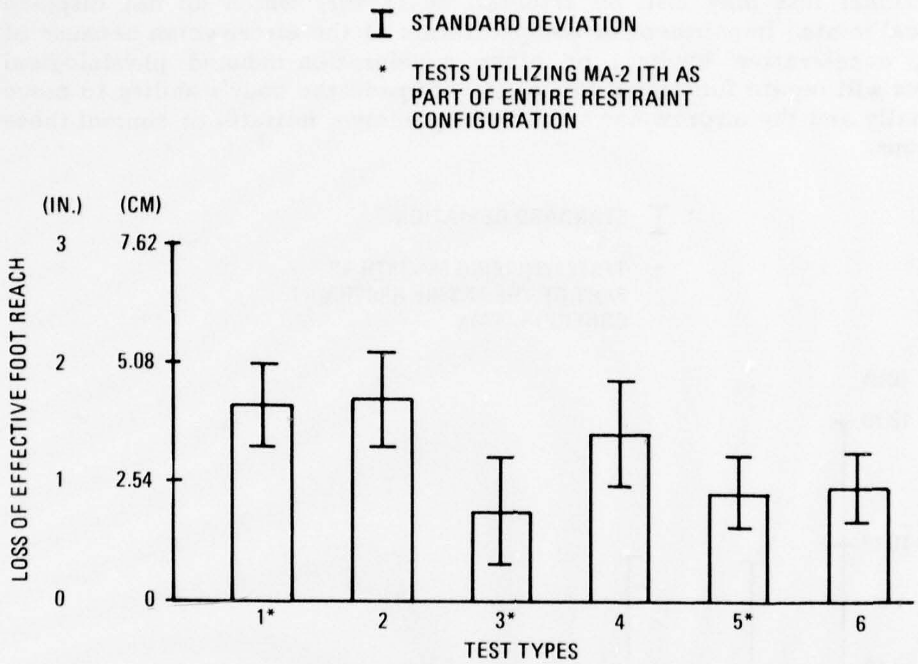



Figure 7
Loss of Effective Foot Reach During -1 Gz

## Loss of Functional Arm Reach

41. Figure 8 displays the amount of loss of effective arm reach which occurred in all subjects. There is significantly greater loss ($P<.05$) when using restraint configurations 1 and 2 than there is for any other combination of restraints. This loss could result in less than optimal control of the aircraft, or in erratic control inputs, and could result in the loss of the aircraft. There was, however, no significant correlation between the observed loss of effective reach and any single variable of body motion (off-seat displacement, torso stretch, shoulder motion, etc.). This lack of correlation requires the introduction of a new term, functional loss, which relates to a restraint system's effectiveness at conserving the aircrewman's ability to retain or regain adequate control of his aircraft. Any undesirable change in the aircrewman's ability to reach or activate controls is an indication of functional loss. The lack of significant correlations observed in these studies of loss of effective reach is due to the multiplicity of factors which affect functional loss:

a. Any deviation from the design functional body position (that posture, under +1 Gz, from which all control placements were determined) will create functional loss at some point in the cockpit. Such deviation will result in displacement of critical joints and may be due to torso stretch, slack in the seating or restraint systems, pilot anthropometry which is incompatible with the cockpit design, or pilot preferences concerning the use of their restraint equipment or seating devices.

b. Functional loss may also be affected by factors which do not displace critical joints. Impairment or incapacitation of the aircrewman because of pain, accelerative loading, or other acceleration-induced physiological causes will create functional loss as they impede the body's ability to move normally and the aircrewman's ability to perceive, initiate, or control these motions.

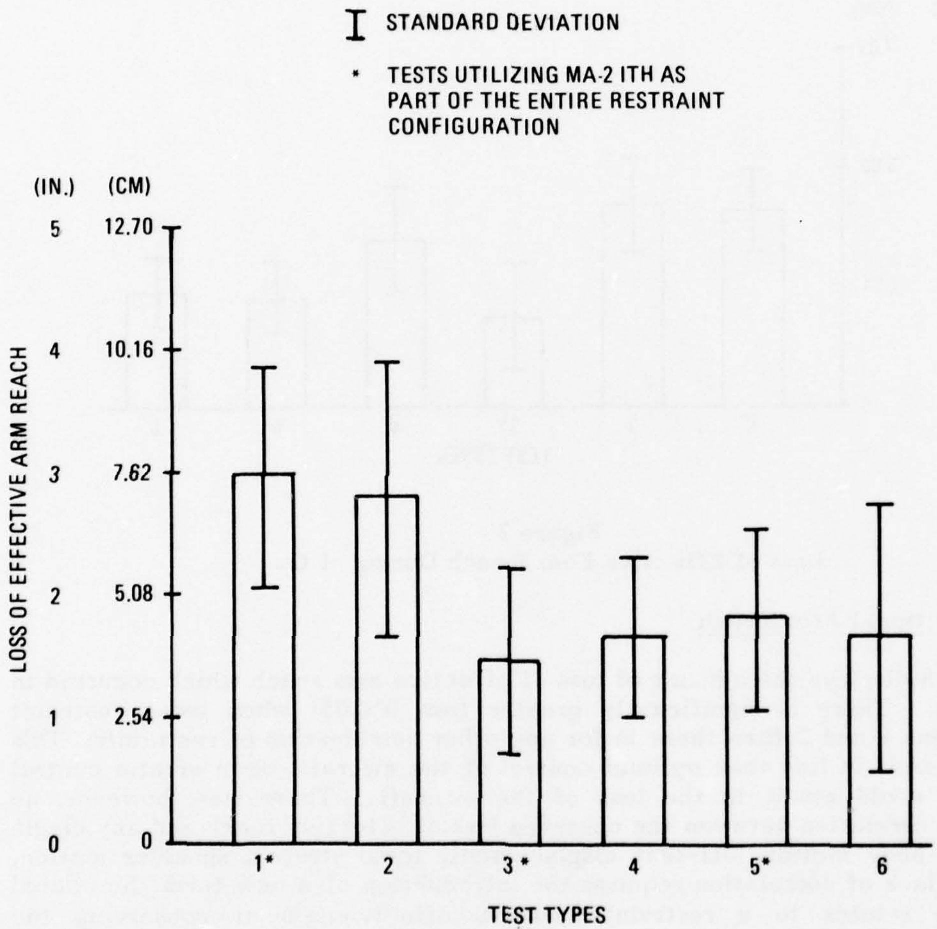



Figure 8
Loss of Effective Arm Reach During -1 Gz

42. It is recommended that functional loss be a concern in all future restraint design evaluations as it directly applies to the ability of the restraint system to assist the aircrewman in the performance of his duties during periods of adverse accelerative influence, without regard to specific tendencies of body shift within those restraints. Functional loss is not, however, an absolute value. Its usefulness is most apparent during a comparative evaluation of two or more systems and should address the effects of:

a. Subject anthropometry.

b. Man-mounted equipment interference.

c. System-induced nuisance (including pain).

d. Accelerative loading.

e. Degradation of effective reach (hands and feet).

f. Visual interference.

MA-2 Integrated Torso Harness

43. The MA-2 torso garment (figure 9) is a man-mounted parachute harness, separate from the parachute and its pack, which incorporates a lap belt and shoulder straps for aircrewman restraint. These two features (parachute harness and aircrew restraint provisions) were combined to achieve certain advantages:

a. Reduction of the donning problems associated with open-webbing harnesses (such as the NB-8), and the problems of donning the parachute harness inside the aircraft (or immediately prior to entering the aircraft) during scramble operations.

b. Simplicity of donning and wearing a reliable parachute harness.

c. Ease of mobility during aircraft ingress and egress and ease of attachment to the restraint subsystems in the aircraft.

d. Simplicity of mounting and integrating survival equipment attained by attaching the parachute to the harness from a separate pack (kept permanently in the aircraft).

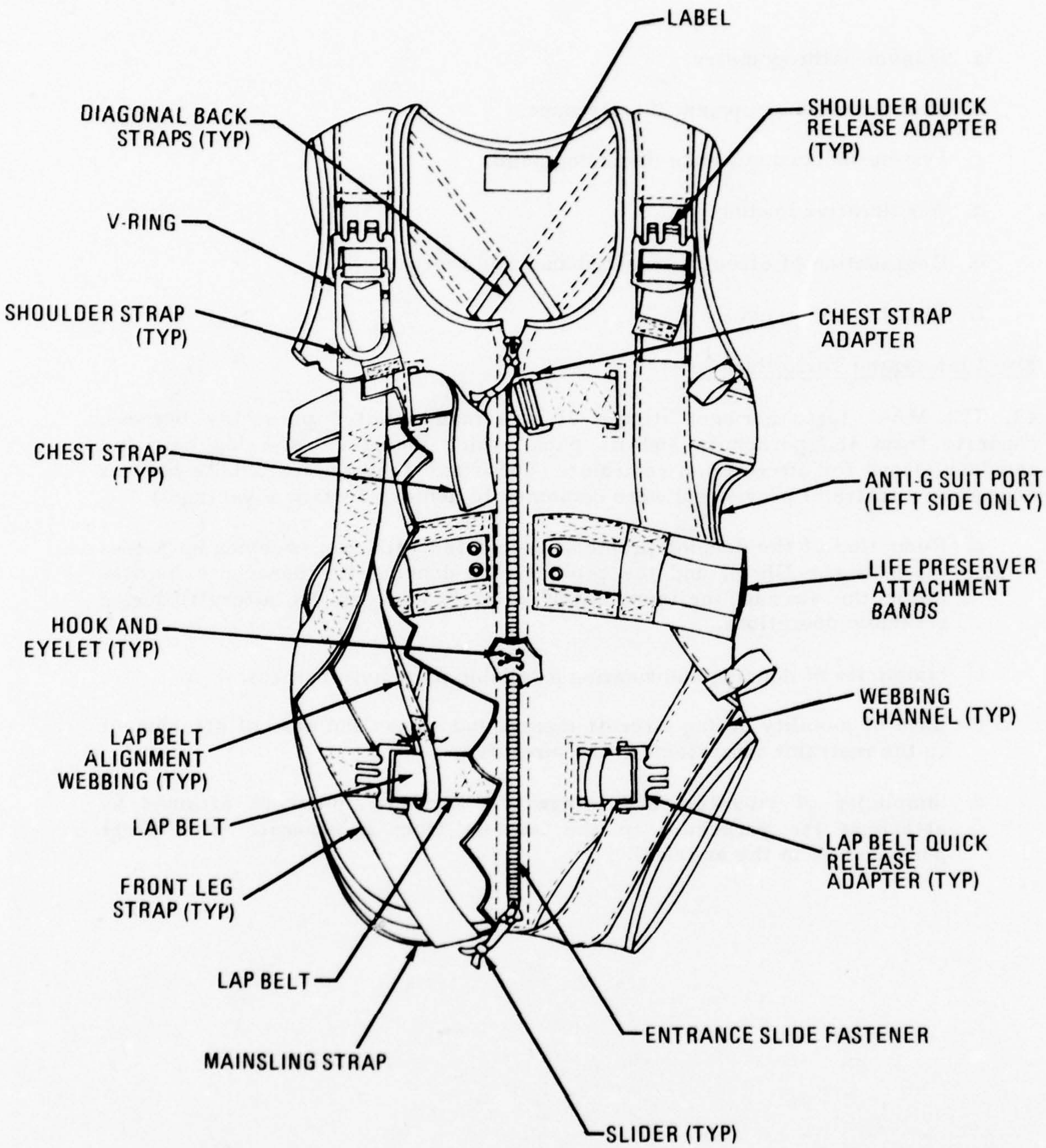



Figure 9
MA-2 Integrated Torso Harness (Redrawn from Aviation Crew Systems Manual (Parachutes), NAVAIR 13-1-6.2 of December 1974).

44. Problems associated with the parachute harness portion of the MA-2 have been discussed in paragraphs 13.a, 13.b, and 13.c. In addition to these, difficulty releasing the parachute riser release fittings has been a leading cause of postlanding parachute entanglement in water.

45. The restraint portion of the MA-2 consists of a short nylon web (lap belt) with a quick-release fitting at each end for attachment to the seat restraint subsystem (figure 10), and two larger fittings on the upper torso (chest) which connect the harness to the parachute and the inertia reel (for restraint against -Gx). The fittings are quick-release types (currently Koch fittings) to facilitate connecting the shoulder restraint/parachute risers to the upper torso and the lap belt anchor straps to the MA-2 lap belt (figure 9).

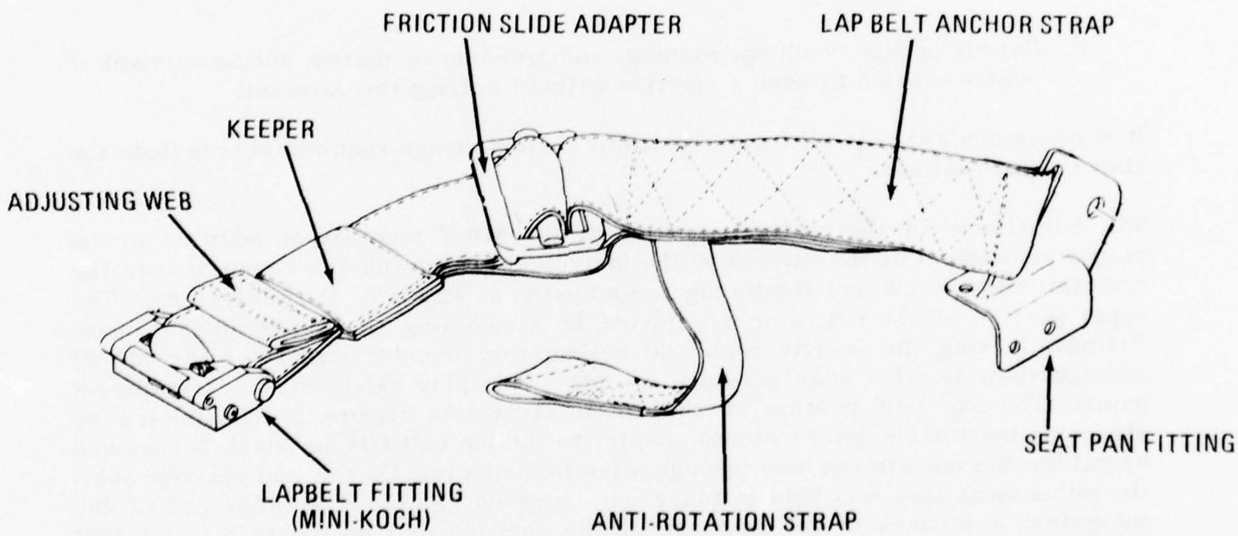



Figure 10
Basic Lap Belt Restraint System (Redrawn from Aviation Crew Systems Manual (Seat Survival Kits), NAVAIR 13-1-6.3 Rapid Action Change No. 2 of November 1973).

**46. The U.S. Air Force uses a partially-integrated torso harness (PCU type) wherein the lower torso restraint is achieved by a separate lap belt restraint system permanently mounted on the ejection seat. Comparative evaluaton of this piece of equipment against the MA-2 was not within the scope of this study. It is recommended that such an evaluation be performed to assess the merits of a pelvic restraint system which is separate from the parachute harness.**

47. Adjustment of the MA-2/MA-2P to the individual should be accomplished outside the aircraft by assuming a semi-seated position, grasping the chest strap and chest connector in each hand, and alternately pulling on these straps until the harness feels snug. This procedure is not listed in NAVAIR 13-1-6.2 although all other functions are. Few aircrew take the time to adjust the garment before each flight and most leave it at its loosest adjustment for comfort in the ready room. Investigative efforts, however, indicate that no difficulty is encountered in properly adjusting the MA-2 to the individual while seated in a variety of fighter and attack aircraft using a subject of 77th percentile seated height. An efficient and effective restraint system should provide:

a. Use of preset or "memory" fitting positions for ready transition from exocraft to endocraft.

b. Permit upright walking and comfort during the transition from the ready room to the cockpit.

c. Permit upright walking, running, and freedom of motion during survival or enemy evasion following ejection without doffing the garment.

It is recommended that all future restraint system design requirements include the above considerations.

48. Adjustment of the restraint portion of the MA-2 involves, in addition to the proper adjustment of the harness to the individual (paragraph 47), connection to the restraint subsystems and tightening the adjustment straps of the subsystems. The upper portion of the restraint is adjusted by connecting the upper quick-release fittings, locking the inertia reel, and pulling the shoulder straps (of the MA-2) through their friction adapters until no more free play exists at the attachment points. The lap belt portion of the restraint system (figure 9) is adjusted by attaching the female quick-release adapter to the lap belt fitting. Slack is removed by pulling the adjustment web through a friction adapter. On the test ejection seat, the adjustment web was held in place with a nylon keeper. The other end of the subsystem is secured to the seat pan of the ejection seat by means of a lap belt anchor strap assembly.

49. The MA-2 consists of nylon webbing for the parachute harness portion and nylon fabric panels (absent on the MA-2 cutaway modification). A comparison of the restraint effectiveness of the lap belt portion only (test configuration 1 versus configuration 2) showed a trend toward less off-seat displacement when the parachute portion of the MA-2 was omitted. Similar trends were observed for all subjects when restraint configurations 3 and 5 were compared to configurations 4 and 6, respectively. While the trend toward less off-seat displacement without the parachute attachment portion of the MA-2 was not statistically significant, it nevertheless suggests that the parachute harness might be detracting from adequate tightening of the lap belt portion of the restraint system. Further investigation is needed, using a larger test population, to verify these suspicions. Statistically significant verification of these suspicions would strongly suggest the need for either separate parachute attachment harness and lower restraint system or an improved integration of these systems.

50. Upon comparing the restraining effect of the MA-2 and the Bypass Web (experimental restraint configurations 1 and 2) with any other combination of test configuration restraints used, the MA-2 and Bypass Web consistently permitted significantly greater off-seat displacement, head displacement, and functional loss. The restraint effectiveness of the MA-2 was improved upon by all other combinations of experimental restraints used in this study. The failure of a restraint system to maintain good seat/man contact degrades the pilot's ability to position and hold controls during departures, spins, and various aerobatic/air combat maneuvers, degrades emergency egress performance, is psychologically distressing, gives a sense of detachment from the airplane, and increases the risk of injury.

51. In the cases in which the test subjects were rotated backwards to the inverted position using experimental restraint configurations 1 and 2, the lap belt quick-release adapters twisted in such a way as to present the upper edge of those adapters to the bony prominence of the iliac crest. The subject's entire weight was then supported on that edge of the adapters. In every case, the subjects reported an extreme amount of pressure being caused by the fittings and, in one case, the experiment had to be temporarily aborted because of the intractable pain being inflicted upon the subject by this pressure. Operational aircrew reports of this problem are infrequent, possibly because of a variety of factors. First, the experimental subjects did not wear the amount of clothing an aircrewman would, which might mask this pressure. Second, the twisting action of the buckle might be caused by the weight distribution of the subjects as they passed from +Gz through +Gx to -Gz. The chance of this particular set of G vectors being identically reproduced during flight is remote, although it is not known if a transition from +Gz through zero Gz to -Gz would create the same problem. This hypothesis is partly substantiated by the fact that none of the subjects reported difficulty when rotated from +Gz through -Gx to -Gz. Finally, the lack of pilot reports on this problem may be due to the diminished perception of the pressure because of overriding needs to regain aircraft control or to initiate ejection. During these periods of extreme psychological stress, it is unlikely that the pilot's attention would be drawn to minor physical distractions, even though those distractions may actually be contributing to his functional loss. For this reason, the identification of such a problem in the laboratory should be given the same consideration as it would if every member of a flight crew reported it. It is recommended that the lap belt attachment fittings be reconfigured in such a way as to eliminate this source of discomfort during adverse accelerative conditions. Laboratory tests, utilizing various foam pad inserts between the fittings and the fabric of the MA-2, successfully eliminated the problem without a noticeable increase in off-seat displacement.

52. In the test ejection seat (Douglas ESCAPAC IC-3 with RSSK-8A seat pan), the angle of the lower restraint subsystem adjustment web to the seat pan became greater when the subjects were inverted (figures 11 and 12). This allowed a measure of vertical travel at the lap belt attachment point and contributed to the overall off-seat displacement and head displacement. It is not known if this problem can be alleviated by changing the geometric configuration of the lap belt subsystem attachment to the seat pan. It is recommended that the angular rotation of the lap belt subsystem with respect to the seat attachment point be further investigated, utilizing a variety of geometric configurations.

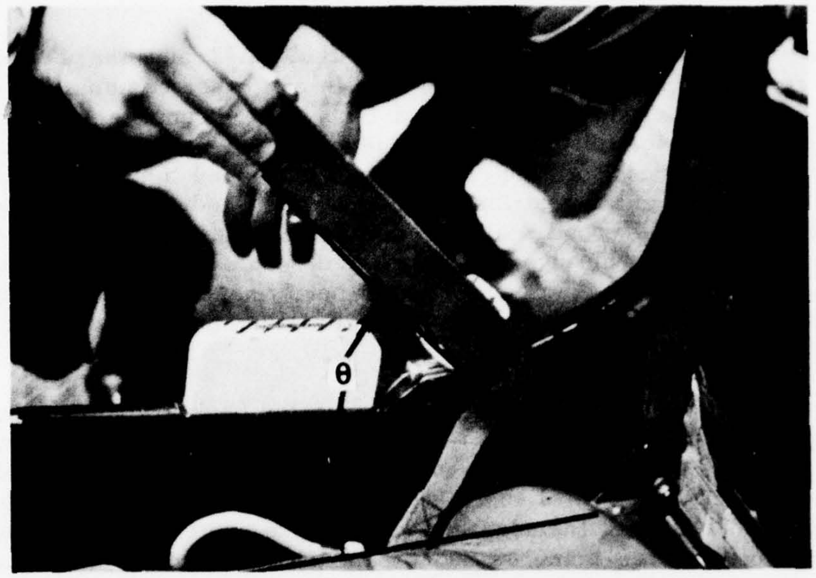



Figure 11
Normal Lap Belt Subsystem Geometry in RSSK-8A


Figure 12
Lap Belt Subsystem Geometry of RSSK-8A,
Stressed Upward During Negative G

53. As demonstrated under laboratory conditions, no significant difference is noted between head displacement, off-seat displacement, or body stretch allowed by the MA-2 and that allowed by the use of the Bypass Web configuration. These data would suggest that the upper restraint portion affords no measurable -Gz restraint. This subjective conclusion is further substantiated by the subjective opinions of the test subjects who reported little or no weight support from the shoulder straps. When subjected to -Gx, however, the upper restraint portion supports the weight of the upper torso, preventing the torso from moving forward beyond certain limits. These limits are determined by:

a. The size of the aircrewman.

b. The looseness of the harness and the tension from adjustment of the upper restraint portion of the MA-2.

c. The 1/2 in. (1.27 cm) free play of the shoulder restraint inertia reel extension web, as permitted by Military Specification MIL-R-81514B, when the take-up reel is locked.

d. The excess web extension when the inertia reel is locked due to web stack-packing on the take-up reel.

The amount of motion permitted by these factors may be sufficient to mask perception by the seat occupant as to the locked/unlocked status of the inertia reel. As discussed in paragraph 14.d, at least one pilot mistakenly assumed that the free play was due to an unlocked inertia reel and, upon cycling his harness lock lever to assure himself that it was locked, inadvertently unlocked the inertia reel and compounded his difficulties.

54. For subjects with small waist girth, it is not possible to fully tighten the lap belt with the nylon keeper in place. This keeper butts against the edge of the friction slide adapter on the lower restraint subsystem preventing any further tightening (figure 13). This problem has been the subject of at least one UR. If the bitter end of the adjustment web is routed outside of the keeper (figure 14), the keeper butts against the friction slide bar in the adapter, forcing it open, and allowing about 1/2 in. (1.27 cm) of slackening at each end of the lap belt when the subject is inverted. For laboratory purposes, the keeper was removed entirely from the lap belt subassembly which eliminated entanglement or jamming problems. This modification allowed full adjustment of the lap belts and all slippage problems related to interference of slide and keeper were thereby eliminated. Interference from the lap belt keeper, preventing adequate tightening of the lap belt, results in poor seat/man contact and degradation of aircrew performance. Design, location, and usage of the lap belt should be reevaluated to determine the advantages or disadvantages of (1) eliminating the nylon keeper on this type of restraint subsystem and (2) requiring subsystem designs which do not incorporate a webbing loop in the tension take-up mechanism.

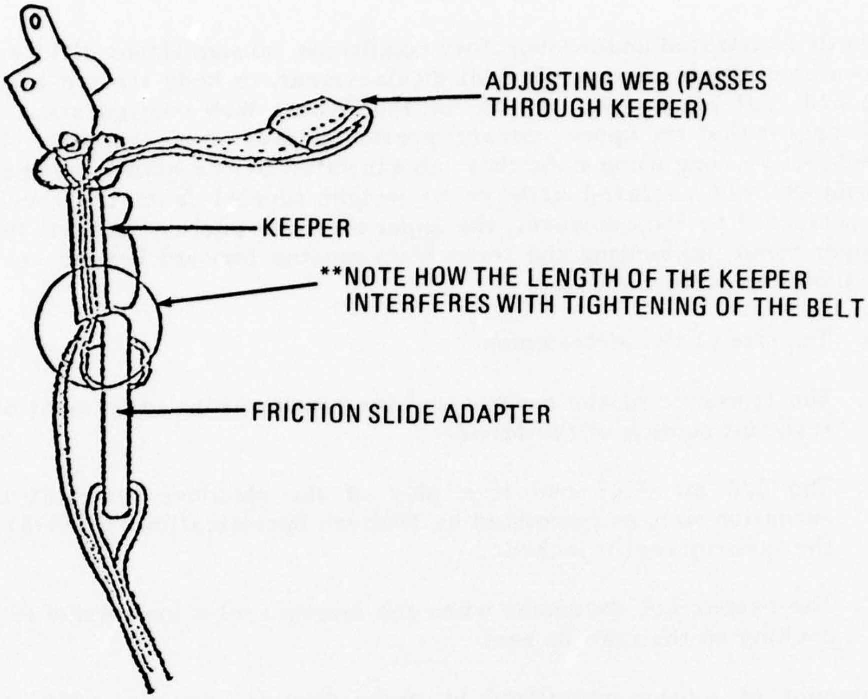



Figure 13
Lap Belt Keeper Butting Against the Friction Slide Adapter

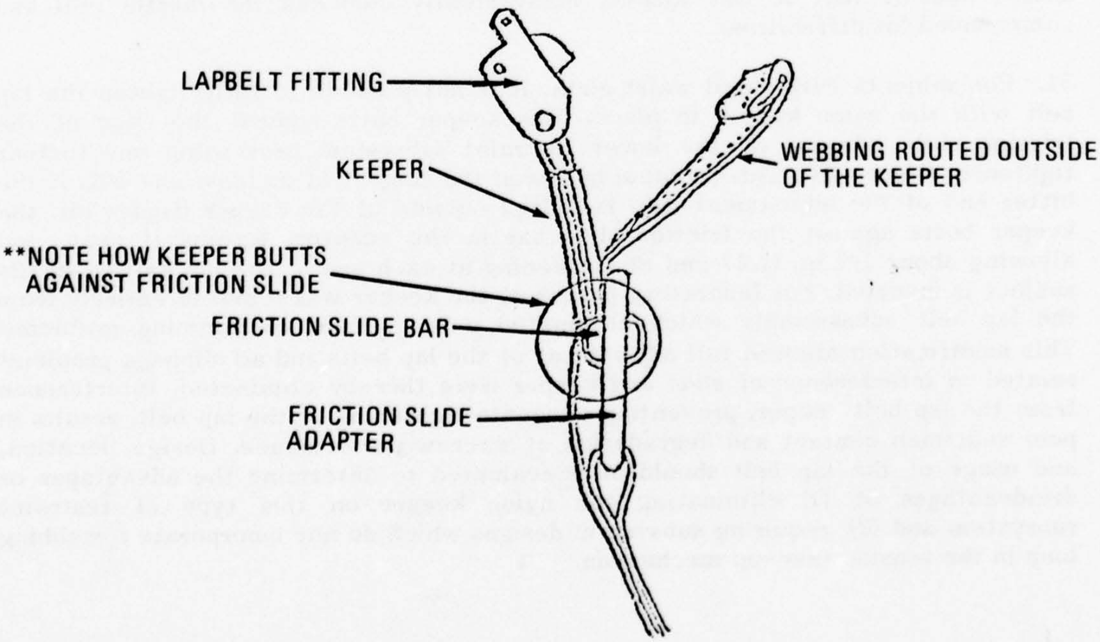



Figure 14
Lap Belt Keeper Butting Against the Friction Slide Bar

55. It has been reported (references 3, 4, and 5) that, during repeated violent motions associated with departure, poststall gyrations, and spins, lap belt friction adapters (MS 22019) loosen, requiring the pilot to continually tighten them. The results of this laboratory study using the same MS 22019 friction adapters indicated that progressive slippage of the adjustment webbing through the friction adapter could occur, especially when alternate tension and relaxation of the webbing was observed. During the tests, no slippage resulted from the load imposed by inverting the subjects. Further studies using a variety of alternating slack-to-taut loads, impact loads, side loads, and suspension loads confirmed these indications of webbing slippage during moderate alternating slack-to-taut loads and impact loads. No slippage resulted from side loads or constant suspension loads. The reports of slippage through the friction adapters, however, could reflect aircrew attempts to explain the cause of apparent lap belt loosening which, in fact, may or may not have been due to actual slippage of the webbing through the friction adapter. Even in the laboratory, gradual slackening of the lap belt occurred, although no indication of slippage was observed. This slackening could be due to a variety of causes including visceral shift, loss of muscle tension, abdominal gas expansion and expulsion, and unconscious manipulation of the lap belt friction adapters for comfort. A loose lap belt, for whatever reason, reduces restraint effectiveness and could result in poor seat/man contact and degradation of pilot performance. The friction adapters examined (MS 22019) should be replaced with adapters which are easier to tighten and which remain tight until intentionally released. The significance of the other factors which could cause loosening of the lap belt requires further study to determine if these factors degrade restraint performance and, if so, whether they can be corrected.

56. Adjustment of the lower restraint subsystem (as observed with the RSSK-8A) cannot be accomplished optimally by the aircrewman due to the angle and direction necessary for the applied force to remove the slack at the adjusting point. The arms cannot apply enough force at these points to fully tighten the belt. In the laboratory, the lap belt was adjusted first by the subject, then by assistants, to a point of no further practical tightening. All body displacements were observed with the lap belt tightened to this point. It is reasonable to expect much greater body displacement in the cockpit, assuming that the aircrewman is the only one effecting lap belt adjustments. In addition to this biomechanical aspect of insufficient vector force, cockpit design may also interfere with optimum restraint adjustment, as it may contain constraints and obstacles which prevent the aircrewman from observing his strap-in progress, from acquiring the necessary purchase on the adjustment straps, or from moving his arms so that he could apply the maximum vector force available. Design, location, and usage of adjustment features should conform to biomechanical requirements for the application of force. Cockpit design and man-mounted equipment design should take into consideration the fact that the aircrewman must be allowed enough freedom to grasp the adjustment portions of his restraints, effect the adjustments, and gauge his progress.

57. The nylon webbing used for adjusting both the upper and lower restraint portions of the MA-2 is prone to binding and jamming within the adjustment fittings. A photograph of the binding tendency of the upper restraint adjustment webbing is presented in figure 15. The binding usually occurs when the strap is adjusted from its fully open (loose) position to the fully closed position quickly. The

reason for this is that the friction adapter, when displaced abruptly during tension take-up, travels faster on the take-up webbing which is between the friction adapter and the harness textile material. This travel causes a loop to form beneath the friction adapter, jamming the mechanism, and causing the perception that all slack has been removed. It is difficult for the wearer to visually check for the presence of such a loop. The binding may work free with time, allowing that side of the harness to become loose. This looseness may have an adverse effect on restraint of the upper torso, allowing the aircrewman to come forward and permitting malpositioning of the aircrewman upon ejection and parachute opening, thereby increasing the risk of injury. The lower restraint subsystem is more susceptible to binding problems as tension take-up of the adjustment web can form a loop between the friction adapter and the lap belt attachment fitting. This loop can jam, causing the perception of a tight lap belt. When the loop works free, that side of the restraint becomes excessively loose and the restraint effectiveness of the system is almost totally forfeited. The end result of this type of binding, when it works free, is that the aircrewman is restrained on only one side, can be displaced upward, and will be put in an unbalanced position conducive to ejection force injuries. Both types of binding and jamming problems can be easily detected and resolved by the aircrewman with proper attention when attaching and adjusting the restraints. It is recommended that future design efforts be directed toward alleviating any adjustment problem which requires concentrated effort on the part of the aircrewman to prevent binding or jamming failures.

Figure 15
Binding of the Upper Restraint Adjustment

58. The current upper torso quick-release parachute release fitting connectors (Koch type) are prone to inadvertent actuation. If the locking bar on the female Koch quick-release fitting is being held down by the spring-loaded cover (figure 16), the connection of that fitting to the male fitting will not be secure. It is possible to insert the male fitting in such a way as to create a snapping sound which very closely resembles the snapping sound for positive locking. Should this occur and if there is a side load on the connectors (figure 16), the aircrewman may erroneously assume that the connector is locked. The end result is a grossly inadequate attachment to the parachute and degradation of -Gx restraint. It is recommended that a positive indication of locking of the shoulder fittings be provided, perhaps in the form of a highly visible coloring of the locking bar.

Figure 16
Side Load Locking of Shoulder Koch Fitting

## Effect of Restraint Placement on the Body

59. Laboratory results of the effect of restraining the feet and thighs are inconclusive. Any recommendations concerning restraint of the feet or thighs must be deferred until sufficient additional tests have been made to permit full observation and evaluation of the possible effects.

60. The effect of restraining the torso (against -Gz) at the shoulders, or attaching restraints in such a fashion that the shoulders are impeded from moving normally, is a restriction of functional ability. In some cases, such as during spin tests in two-place aircraft (with one pilot wearing an acceptable harness) or during emergency egress, restraint of the torso in such a manner as to immobilize the shoulders, support torso weight at the shoulders, or otherwise restrict mobility of the shoulders, may be acceptable. It is recommended that further studies be conducted to determine the desirability of shoulder restraint against -Gz under specific flight conditions and the feasibility of such restraint without impairment of functional ability.

Other Considerations

61. Present restraint system design approaches assume the body to be a solid mass against which a solid restraint system will act. Actually, the human body reacts to acceleration as a fluid which is contained by a semi-elastic covering (skin) and arranged upon a jointed, moveable frame (skeleton). Any solid restraint system (belts, bars, etc.) must act upon the frame in order to be effective. However, in order to apply restraint against the skeleton, restraint must first act through the flesh which covers the skeleton. Not only does the flesh act as a damper upon the restraint, but it also flows around the restraint to escape containment. In the laboratory, the lower restraints (waist, thighs) consistently failed to constrain visceral shift, resulting in varying degrees of off-seat displacement.

62. The fluid tendencies of the body can be effectively countered by proper restraint design. A wide belt restraint, applied to the same general area as a narrow belt restraint, may not be as susceptible to fluid shifts because of the increased displacement required of those fluids to escape containment. The width of the belt, however, is limited according to the area upon which restraint is to be applied, as present restraint textiles are too stiff to follow bends and curves in the body. A possible alternative to the single, wide belt would be a set of parallel narrow belts covering a wide area of the body which would follow complex curves without buckling. One other solution might be to replace the nylon belts with a nylon mesh, covering those portions of the body where restraint is desired. Such a mesh could be "programmed" to respond to acceleration by applying restraint and by concentrating that restraint on the body part requiring the most restraint to allow the aircrewman to maintain control over the aircraft. The concept of man as a fluid mechanism must be taken into consideration whenever designing a restraint device. The body must be forced to conform to a solid frame by the restraint while accelerative forces demand that the body move relative to that frame.

63. Cockpit design can be optimized to reduce the functional loss caused by restraint systems. For example, functional loss (for the same amount of displacement) is not as great if the pilot has a side-arm-mounted control stick than if he is equipped with a conventional centrally-mounted (floor or panel) control. The apparent tradeoff is due to the elimination of the requirement to reach around the body to gain contact with the controls, the additional support available to the arm (reducing both the force needed to move the arm and the difficulty of gauging control motions), the reference plane given to the arm by the support, and the reduced need to apply motive force to the entire arm.

64. New restraint system designs must be thoroughly tested under actual and laboratory environmental conditions utilizing a wide varity of subject anthropometry and seat types to evaluate design performance relative to known restraint systems. Comparative evaluation is a prerequisite to acceptance of any new design as it is the only means of testing which can provide an accurate assessment of design improvements. Additional studies may be required to develop evaluative tools and procedures which will eliminate the human variability, experiment biasing, and other error-producing influences which might be encountered during comparative evaluations.

## AIRCREW PERSONNEL RESTRAINT QUESTIONNAIRE

65. An Aircrew Personnel Restraint Questionnaire (appendix I) was developed by the Naval Air Development Center and solicited to U.S. Naval Aviators and Naval Flight Officers flying tactical jet aircraft which utilize the MA-2 Integrated Torso Harness. Completion of the questionnaire was coordinated by area Aeromedical Safety Operations (AMSO) Physiologists. One thousand questionnaires were solicited and 982 were returned for analysis.

66. The Naval Weapons Engineering Support Activity (NAVWESA) computerized and quantified each question (appendix I). In addition to performing general data reduction tasks, NAVWESA was requested to answer specific queries (appendix J) and address any additional points which would tend to either confirm or refute the tentative conclusions of this study.

67. The specific questions posed to NAVWESA were directed at four general areas:

a. Adequacy of the MA-2 in providing restraint.

b. Adequacy of restraint subsystem components.

c. Attitudes of aircrewmen towards restraint.

d. Fleet satisfaction and acceptance of the present restraint subsystems and the MA-2.

Of special interest to the study was whether or not there were variations in questionnaire answers of particular population groupings. The population groups of interest are identified in table XVII.

Table XVII

MA-2 Questionnaire Population Groups of Interest

| Population Group | Population Size | Description |
|---|---|---|
| All | 982 | All questionnaire responders |
| No Control Loss | 495 | All responders that never lost control of aircraft |
| Loss, MA-2 Deficiency | 41 | Responders that<br>a. Lost control of aircraft<br>b. Blamed MA-2 for the loss of control, and<br>c. Indicated MA-2 interfered with regaining control |
| Loss, No MA-2 Deficiency | 334 | Responders that lost control of aircraft but did not blame the MA-2 |
| Special Fit | 663 | Responders specially fitted for their MA-2 |
| No Special Fit | 316 | Responders not specially fitted for their MA-2 |
| Head-Canopy | 694 | Responders that experienced head-to-canopy contact |
| No Head-Canopy | 286 | Responders that did not experience head-to-canopy contact |

68. The following sections address the specific queries within each general area presented to NAVWESA for analysis. Where applicable and appropriate, the variation among the different population groups is given as requested. It should be noted that the data contained herein are presented at the summary level after a considerable amount of intermediate data reduction. Additional and more detailed data are available from NAVWESA (NAVWESA-19).

## ADEQUACY OF THE MA-2 IN PROVIDING RESTRAINT

69. <u>Evidence of Difficulty Adjusting the MA-2 to the User</u>. All population groups expressed an apparent ease in both donning and doffing the MA-2 Integrated Torso Harness. As indicated in tables XVIII and XIX, the variations among groups were relatively insignificant. One anomaly was noted, however, and while minor, it is

included for completeness. A detailed analysis of the questionnaire responses revealed that although the number of aircrewmen experiencing difficulty in doffing the MA-2 was small (46 of 982), 85% of these (39 of 46) were specially fitted for the MA-2.

70. MA-2 Specifically Addressed as the Cause for Loss of Aircraft Control. Loss of aircraft control was experienced by 415 responders of which 75 attributed the control loss to deficiencies in the MA-2 Integrated Torse Harness and related subsystems. Loss of control occurred in the maneuvers and aircraft attitudes listed by predominance in table XX. Aircrew comments regarding the MA-2 deficiencies that caused or contributed to aircraft control loss are summarized in table XXI. In general, the comments presented in table XXI indicate poor restraint and are directed at the lap belt subsystem

Table XVIII

Difficulty in Donning the MA-2 Integrated Torso Suit by Population Group

Questionnaire No. 10A - Do you usually have difficulty donning your MA-2 integrated torso suit?

| Population Group | Population Size | % Yes | % No | % Blank |
|---|---|---|---|---|
| All | 982 | 12 | 87 | 0 |
| No Control Loss | 495 | 12 | 87 | 0 |
| Loss, MA-2 Deficiency | 41 | 13 | 87 | 0 |
| Loss, No MA-2 Deficiency | 334 | 12 | 86 | 1 |
| Special Fit | 663 | 11 | 87 | 1 |
| No Special Fit | 316 | 14 | 86 | 0 |
| Head-Canopy | 694 | 13 | 86 | 0 |
| No Head-Canopy | 286 | 10 | 89 | 1 |

Table XIX

Difficulty in Doffing the MA-2 Integrated Torso Suit by Population Group

Questionnaire No. 10B - Do you usually have difficulty doffing your MA-2 integrated torso suit?

| Population Group | Population Size | % Yes | % No | % Blank |
|---|---|---|---|---|
| All | 982 | 4 | 93 | 3 |
| No Control Loss | 495 | 4 | 93 | 3 |
| Loss, MA-2 Deficiency | 41 | 6 | 93 | 0 |
| Loss, No MA-2 Deficiency | 334 | 5 | 93 | 2 |
| Special Fit | 663 | 6 | 91 | 2 |
| No Special Fit | 316 | 2 | 95 | 3 |
| Head-Canopy | 694 | 5 | 92 | 3 |
| No Head-Canopy | 286 | 3 | 95 | 2 |

Table XX

Predominant Maneuvers and Aircraft Attitudes during which MA-2 Deficiencies Contributed to Loss of Control

| Percent Occurrence | Maneuver or Aircraft Attitude |
|---|---|
| 40 | Negative "G" |
| 13 | ACM |
| 7 | Inverted |
| 4 | Departures |
| 3 | Roll |
| 3 | Inverted Spin |
| 3 | Departures (violent gun defense) |
| 3 | Spin |

Table XXI

MA-2 Deficiencies Causing or Contributing to Control Loss during Maneuvers or in Adverse Aircraft Attitudes

| Noted Deficiency | Number of Citations |
|---|---|
| Can't get lap belt tight enough | 17 |
| Poor lap/shoulder restraint system | 17 |
| Can't get full use of rudders | 5 |
| Lap belt works itself loose | 5 |
| Lateral Restraints | 4 |
| Doesn't permit sufficient "trunk twisting" (in ACM and similar maneuvers) | 3 |

71. MA-2 Specifically Addressed as Cause for Difficulty in Recovering Aircraft Control. Of the 415 responders who had experienced loss of aircraft control, 65 indicated that the MA-2 hindered the attempt to regain control. Furthermore, 41 of these 65 had also attributed the initial control loss to a deficiency in the MA-2 Integrated Torso Harness. As indicated by the aircrew comments given in table XXII, poor restraint is again considered to be the major factor causing the pilot to float out of the seat and away from the controls (specifically, stick and rudder).

72. Sample Population(s) Express a Desire for an Improved Restraint System. Although this question was not posed directly in the Aircrew Personnel Restraint Questionnaire, individual comments made by those surveyed indicated a definite need for improved restraint. These comments were noted among all population groups and especially among those aircrewmen who attributed aircraft control loss to a deficiency in the MA-2 Integrated Torso Harness (refer also to paragraphs 74 and 75).

73. MA-2 Reported as Being an Inadequate Restraint System. Approximately 69% of those surveyed considered the MA-2 Integrated Torso Harness to be an adequate restraint system. On the contrary, many individual responses were qualified by either noting the absence of alternative restraint systems or by indicating MA-2 deficiencies requiring improvement. Some differences of opinion were noted between the population groups of interest as shown in table XXIII. As might be expected, aircrewmen attributing loss of aircraft control to a deficiency in the MA-2 Integrated Torso Harness were more apt to consider the system as being inadequate.

Table XXII

MA-2 Related Deficiencies Causing Difficulty in Recovering Aircraft Control

| Reason for Difficulty in Recovering Control | Percent Occurrence |
|---|---|
| Tight lap belt still float out of seat | 11 |
| During 0 G or (-) G, the seat pan floats out of seat | 9 |
| Not held to seat no matter how tight | 9 |
| Pilot forced away from seat and rudder pedal | 8 |
| Rise out of seat in less than 1 G and lose rudder pedal contact | 6 |
| Pilot floated away from seat and stick during (-) G | 6 |
| (-) G | 6 |
| Inverted hung in straps makes accurate stick positioning difficult | 5 |
| No lateral restraint | 5 |
| Straps don't hold occupant down to seat | 5 |
| Torso straps were tight but in flight had excessive vertical movement | 3 |
| Excessive body movement | 3 |
| Buttock to seat contact was lost and pilot was forced away from controls | 3 |
| Lack of restraint when less than Ø G | 3 |

Table XXIII

Adequacy of MA-2 Restraint System

Questionnaire No. 30 - Do you consider the MA-2 integrated restraint configuration an adequate restraint system?

| Population Group | Population Size | % Yes | % No | % Blank |
|---|---|---|---|---|
| All | 982 | 79 | 18 | 3 |
| No Control Loss | 495 | 80 | 16 | 4 |
| Loss, MA-2 Deficiency | 41 | 46 | 51 | 3 |
| Loss, No MA-2 Deficiency | 334 | 85 | 12 | 3 |
| Special Fit | 663 | 81 | 16 | 3 |
| No Special Fit | 316 | 73 | 22 | 5 |
| Head-Canopy | 694 | 74 | 22 | 4 |
| No Head-Canopy | 286 | 90 | 8 | 2 |

74. Deficiencies found to Exist in the MA-2. MA-2 deficiencies were noted among all population groups of interest. As might be expected, deficiencies noted were more pronounced in those population groups experiencing difficulty, such as loss of aircraft control or head-to-canopy contact. Table XXIV summarizes the extent to which the population groups cited deficiencies in the MA-2.

Table XXIV

Population Group Summary Regarding MA-2 Deficiencies

Questionnaire No. 31 - Do you feel there are any deficiencies with the MA-2 integrated restraint system?

| Population Group | Population Size | % Yes | % No | % Blank |
|---|---|---|---|---|
| All | 982 | 54 | 41 | 5 |
| No Control Loss | 495 | 45 | 47 | 7 |
| Loss, MA-2 Deficiency | 41 | 93 | 7 | 0 |
| Loss, No MA-2 Deficiency | 334 | 58 | 40 | 2 |
| Special Fit | 663 | 51 | 42 | 6 |
| No Special Fit | 316 | 61 | 36 | 3 |
| Head-Canopy | 694 | 62 | 33 | 5 |
| No. Head-Canopy | 286 | 36 | 60 | 4 |

75. Deficiencies Specifically Identified in the MA-2. Specific deficiencies were noted in the MA-2 Integrated Torso Harness by each of the population groups. As shown in table XXV, the type and predominance of specific MA-2 deficiencies was similar across population groups with the exception of those aircrewmen who attributed loss of aircraft control to the MA-2. It should be noted that the percentages given in table XXV are based upon the total number of MA-2 deficiencies cited by the particular population groups. Hence, multiple deficiencies listed by an individual responder are included. This explains why the total number of deficiencies cited by the third population group (Loss MA-2 Deficiency) is 72 and yet the total number of responders within this group is only 41 (refer to table XVII). As can be seen in table XXV, the predominant MA-2 deficiencies cited across all population groups of interest are:

a. Can't get lap belt tight enough.

b. Poor restraint in negative G's.

c. Lack of comfort.

d. Lap belt works loose.

e. Poor lap/shoulder restraint subsystem.

## Table XXV

### Distribution Percentage of MA-2 Deficiencies by Population Group

| MA-2 Deficiency Cited | Population Group Percentage of Occurrence | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | All % | No Control Loss % | Loss MA-2 Deficiency % | Loss No MA-2 Deficiency % | Special Fit % | No Special Fit % | Head Canopy % | No Head Canopy % |
| Can't get lap belt tight enough | 10 | 10 | 19 | 8 | 11 | 9 | 11 | 8 |
| Poor restraint in negative G's | 9 | 7 | 14 | 7 | 8 | 9 | 9 | 5 |
| Lack of comfort | 8 | 8 | 7 | 9 | 7 | 8 | 7 | 8 |
| Lap belt works loose | 7 | 8 | 4 | 6 | 8 | 7 | 7 | 7 |
| Poor lap/shoulder restraint system | 5 | 4 | 11 | 3 | 5 | 4 | 5 | 5 |
| Incorporate survival vest into harness | 4 | 3 | 4 | 8 | 4 | 4 | 5 | 3 |
| Insufficient trunk twisting in ACM | 4 | 4 | 3 | 3 | 3 | 4 | 4 | 2 |
| Straps in crotch are binding | 3 | 5 | - | 3 | 3 | 3 | 2 | 7 |
| Can't get harness tight enough | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 4 |
| Poor adjustments | 2 | 2 | 3 | 3 | 2 | 3 | 2 | 2 |
| Lateral restraint | 2 | 2 | 3 | - | 3 | - | 2 | 2 |
| Leg straps fit poorly | 2 | 2 | - | 3 | 2 | 2 | 2 | 3 |
| Too Bulky | 2 | 2 | - | 5 | 2 | - | 2 | - |
| Poor lap belt system | 2 | 2 | 3 | - | 2 | - | 2 | - |
| Difficult to don | 1 | 1 | - | 2 | - | 3 | 1 | 2 |
| Shoulder harness loosens | 1 | 2 | - | - | 1 | - | 1 | 2 |
| Need to keep seat pan down tight | 1 | 1 | 3 | - | - | 3 | 1 | 3 |
| Upper Koch leaves shoulder bruises | - | 2 | - | - | 2 | - | - | 3 |
| Total Deficiencies Cited | 790 | 322 | 72 | 241 | 496 | 292 | 642 | 148 |

Table XXVI

Difficulty Encountered in Tightening the Lap Belt

Questionnaire No. 11 - Do you normally experience any problems tightening the lap belt straps while in the seat?

| Population Group | Polulation Size | % Yes | % No | % Blank |
|---|---|---|---|---|
| All | 982 | 38 | 61 | 0 |
| No Control Loss | 495 | 34 | 65 | 1 |
| Loss, MA-2 Deficiency | 41 | 37 | 63 | 0 |
| Loss, No MA-2 Deficiency | 334 | 37 | 63 | 0 |
| Special Fit | 663 | 37 | 62 | 0 |
| No Special Fit | 316 | 40 | 59 | 0 |
| Head-Canopy | 694 | 43 | 56 | 0 |
| No Head-Canopy | 286 | 26 | 73 | 1 |

77. Specific Aircraft in which Subsystem Difficulties have been Encountered. Specific aircraft types were identified with respect to lap belt restraint subsystem difficulties. Table XXVII summarizes the specific aircraft types cited by aircrewmen as to having MA-2 deficiencies. Also shown in table XXVII is the distribution of total aircraft type occurrence reported in the entire restraint questionnaire. Based upon the distribution of total aircraft type occurrence, MA-2 deficiencies are greater than expected for both the A-4 and A-7 aircraft; less than would be expected for the T-2, A-6, and F-9; and just about what would be expected for the other aircraft. Table XXVIII shows the percent distribution of aircraft types with cited MA-2 deficiencies across all population groups of interest. As can be seen, A-4 and A-7 deficiencies highlight the two population groups experiencing aircraft control loss.

78. Inflight Readjustment of the Lower Restraint Subsystem. As shown in table XXIX, only about 10% of those surveyed in each population group indicated that they normally loosen the lap belt due to discomfort. However, this number may be misleading, based upon the distribution of lap belt adjustment intervals given in table XXX. In any event, the data shown in tables XXIX and XXX indicate only minor variations between the population groups with respect to lap belt adjustment.

Table XXVII

Comparison of % Aircraft Types Cited for MA-2 Deficiencies with the Total Occurrence of the Given Aircraft Type

| Aircraft Type | Number Aircraft Cited with MA-2 Deficiency | % with MA-2 Deficiency | % Occurrence in Questionnaire |
|---|---|---|---|
| A-4 | 165 | 39 | 30 |
| A-7 | 81 | 19 | 8 |
| F-4 | 61 | 14 | 14 |
| All Aircraft | 50 | 12 | -- |
| T-2 | 22 | 5 | 17 |
| A-6 | 18 | 4 | 8 |
| F-14 | 8 | 2 | 2 |
| F-8 | 6 | 1 | 2 |
| S-3 | 6 | 1 | 1 |
| F-9 | 5 | 1 | 9 |
| TOTAL | 422 | | |

| Aircraft Type | Number Aircraft Cited with MA-2 Deficiency | All % | No Control Loss % | Loss, MA-2 Deficiency % | MA-2 Deficiency % | Special Fit % | No Special Fit % | Head-Canopy % | No Head-Canopy % |
|---|---|---|---|---|---|---|---|---|---|
| A-4 | 165 | 39 | 35 | 49 | 37 | 38 | 39 | 39 | 34 |
| A-7 | 81 | 19 | 15 | 29 | 26 | 19 | 18 | 18 | 21 |
| F-4 | 61 | 14 | 13 | 6 | 15 | 15 | 13 | 15 | 9 |
| All Aircraft | 50 | 12 | 14 | 11 | 11 | 11 | 12 | 12 | 9 |
| T-2 | 22 | 5 | 6 | 6 | 1 | 5 | 5 | 5 | 5 |
| A-6 | 18 | 4 | 7 | 4 | 2 | 4 | 4 | 3 | 9 |
| F-14 | 8 | 2 | 1 | 2 | 3 | 1 | 3 | 2 | 1 |
| F-8 | 6 | 1 | 1 | -- | 3 | 2 | 1 | 2 | -- |
| S-3 | 6 | 1 | 2 | -- | -- | 1 | 1 | 1 | 5 |
| F-9 | 5 | 1 | 2 | -- | -- | 1 | -- | 1 | 2 |
| TOTAL | 422 | | | | | | | | |

Table XXIX

Tendency to Loosen the Lap Belt Due to Discomfort

Questionnaire No. 15 - Do you normally loosen your lap belt due to discomfort?

| Population Group | Population Size | % Yes | % No | % Blank |
|---|---|---|---|---|
| All | 982 | 10 | 88 | 2 |
| No Control Loss | 495 | 10 | 87 | 2 |
| Loss, MA-2 Deficiency | 41 | 10 | 88 | 2 |
| Loss, No MA-2 Deficiency | 334 | 9 | 90 | 0 |
| Special Fit | 663 | 10 | 89 | 1 |
| No Special Fit | 316 | 12 | 86 | 2 |
| Head-Canopy | 694 | 12 | 86 | 1 |
| No Head-Canopy | 286 | 7 | 91 | 2 |

Table XXX

Distribution of Lap Belt Adjustment Times

Questionnaire No. 16 - After what length of time does discomfort necessitate readjustment of the lap belt straps?

| Population Group | Population Size | Adjustment Time Distribution | | | | |
|---|---|---|---|---|---|---|
| | | % 1/2 hr | % 1/2-1 hr | % 1-2 hr | % 2 hr | % Blank |
| All | 982 | 4 | 7 | 14 | 33 | 42 |
| No Control Loss | 495 | 3 | 7 | 15 | 34 | 41 |
| Loss, MA-2 Deficiency | 41 | 2 | 10 | 10 | 44 | 34 |
| Loss, No MA-2 Deficiency | 334 | 5 | 5 | 12 | 33 | 45 |
| Special Fit | 663 | 4 | 6 | 14 | 34 | 42 |
| No Special Fit | 316 | 3 | 9 | 15 | 30 | 43 |
| Head-Canopy | 694 | 4 | 8 | 16 | 32 | 40 |
| No Head-Canopy | 286 | 3 | 6 | 9 | 35 | 47 |

79. Inflight Readjustment of the Shoulder Restraint Subsystem. Only slight variations were noted across the population groups of interest with regard to the upper restraint subsystem. Most aircrewmen (approximately 75%) had the inertia reel locked only during takeoff and landings, as indicated in table XXXI. Minimal use of the shoulder strap adjusters was also shown to be the case across all population groups as is evident from the data presented in table XXXII. In addition, the amount of adjustment provided by the shoulder strap adjusters was reported to be sufficient by all groups (table XXXIII).

80. MA-2 Comfort. Aircrewmen responses with regard to the comfort of the MA-2 Integrated Torso Harness are summarized across all population groups in table XXXIV. As can be seen, the majority in each group considered the MA-2 to be slightly uncomfortable. This is probably due to the fact that almost all aircrewmen have a tendency to wear the MA-2 either tight or snug, rather than loose. In general, optimal restraint under all flight conditions is preferred to comfort by most aircrewmen.

Table XXXI

Use of Inertia Reel Summarized by Population Group

Questionnaire No. 17 - Approximately what percentage of the time do you fly with the inertia reel locked?

| Population Group | Population Size | Only T.O. + L. % | 10% | 25% | 50% | 75% | Blank % |
|---|---|---|---|---|---|---|---|
| All | 982 | 75 | 10 | 4 | 4 | 2 | 5 |
| No Control Loss | 495 | 73 | 9 | 5 | 5 | 3 | 5 |
| Loss, MA-2 Deficiency | 41 | 63 | 15 | 7 | 7 | 5 | 2 |
| Loss, No MA-2 Deficiency | 334 | 79 | 9 | 2 | 3 | 0 | 7 |
| Special Fit | 663 | 76 | 9 | 4 | 4 | 2 | 5 |
| No Special Fit | 316 | 73 | 10 | 4 | 4 | 3 | 5 |
| Head-Canopy | 694 | 77 | 9 | 3 | 4 | 2 | 5 |
| No Head-Canopy | 286 | 71 | 11 | 5 | 6 | 2 | 5 |

Table XXXII

Use of Shoulder Strap Adjusters by Population Groups

Questionnaire No. 18 - Do you usually use the shoulder strap adjusters on the MA-2 Integrated Torso Harness?

| Population Group | Population Size | % Yes | % No | % Blank |
|---|---|---|---|---|
| All | 982 | 9 | 89 | 1 |
| No Control Loss | 495 | 10 | 88 | 2 |
| Loss, MA-2 Deficiency | 41 | 7 | 93 | 0 |
| Loss, No MA-2 Deficiency | 334 | 8 | 91 | 1 |
| Special Fit | 663 | 11 | 88 | 1 |
| No Special Fit | 316 | 6 | 93 | 1 |
| Head-Canopy | 694 | 9 | 90 | 1 |
| No Head-Canopy | 286 | 10 | 89 | 1 |

Table XXXIII

Sufficiency of Shoulder Strap Adjusters Across Population Groups

Questionnaire No. 19 - Is the amount of adjustment provided (in the shoulder strap adjusters) sufficient?

| Population Group | Population Size | % Yes | % No | % Blank |
|---|---|---|---|---|
| All | 982 | 43 | 9 | 48 |
| No Control Loss | 495 | 46 | 10 | 44 |
| Loss, MA-2 Deficiency | 41 | 32 | 10 | 58 |
| Loss, No MA-2 Deficiency | 334 | 42 | 9 | 49 |
| Special Fit | 663 | 47 | 8 | 45 |
| No Special Fit | 316 | 34 | 13 | 53 |
| Head-Canopy | 694 | 41 | 10 | 49 |
| No Head-Canopy | 286 | 47 | 8 | 45 |

Table XXXIV

MA-2 Comfort Ratings Across Population Groups

| Population Group | Population Size | Uncomfortable % | Slightly Uncomfortable % | Comfort % | % Blank |
|---|---|---|---|---|---|
| All | 982 | 9 | 56 | 34 | 1 |
| No Control Loss | 495 | 9 | 56 | 34 | 1 |
| Loss, MA-2 Deficiency | 41 | 5 | 76 | 19 | 0 |
| Loss, No MA-2 Deficiency | 334 | 9 | 53 | 36 | 2 |
| Special Fit | 663 | 8 | 53 | 38 | 1 |
| No Special Fit | 316 | 10 | 62 | 27 | 1 |
| Head-Canopy | 694 | 10 | 54 | 35 | 1 |
| No Head-Canopy | 286 | 5 | 61 | 34 | 0 |

81. Restraint Attitudes. There was minimal variation among the different population groups regarding the manner in which the MA-2 Integrated Torso Harness is worn. Table XXXV shows that 98% of all aircrewmen wear the MA-2 either tight or snug (approximately 43% tight and 55% snug) rather than loose. The emphasis on a snug or tight fitting MA-2 indicates that most aircrewmen prefer optimal restraint to comfort. This is reflected in the responses to Questionnaire No. 9, which are summarized by population group in table XXXVI. As shown in this table, most groups favor restraint over comfort by a three to one margin, with minor variations in the respective percentages favoring restraint or comfort among the groups. An exception, however, is the group comprised of those aircrewmen attributing loss of aircraft control to a deficiency in the MA-2. This group displays a greater affinity for comfort than all of the other groups. It is possible that this attitude, perhaps unknowingly, is reflected in this group's usage of the restraint subsystems. For example, a lap belt which seems tight to members of this group may in fact be snug or even somewhat loose to others, thereby creating a situation which would increase the possibility of aircraft control loss.

Table XXXV

Manner of Wearing Torso Suit Across Population Groups

| Population Group | Population Size | Manner of Wearing Torso Suit % Tight | % Snug | % Loose | % Blank |
|---|---|---|---|---|---|
| All | 982 | 43 | 55 | 1 | 1 |
| No Control Loss | 495 | 45 | 53 | 1 | 1 |
| Loss, MA-2 Deficiency | 41 | 41 | 59 | 0 | 0 |
| Loss, No MA-2 Deficiency | 334 | 41 | 57 | 1 | 1 |
| Special Fit | 663 | 43 | 55 | 1 | 0 |
| No Special Fit | 316 | 43 | 55 | 1 | 1 |
| Head-Canopy | 694 | 44 | 54 | 1 | 0 |
| No Head-Canopy | 286 | 43 | 55 | 1 | 1 |

Table XXXVI

Comfort and Restraint Attitudes Across Population Groups

| Population Group | Population Size | % Comfort | % Restraint | % Both | % Blank |
|---|---|---|---|---|---|
| All | 982 | 20 | 70 | 8 | 2 |
| No Control Loss | 495 | 19 | 73 | 7 | 1 |
| Loss, MA-2 Deficiency | 41 | 29 | 56 | 15 | 0 |
| Loss, No MA-2 Deficiency | 334 | 21 | 67 | 10 | 2 |
| Special Fit | 663 | 18 | 71 | 8 | 2 |
| No Special Fit | 316 | 23 | 68 | 8 | 1 |
| Head-Canopy | 694 | 21 | 69 | 8 | 2 |
| No Head-Canopy | 286 | 16 | 75 | 8 | 1 |

82. Lap Belt Adjustment Tendencies. Although this question was not posed directly in the Aircrew Personnel Restraint Questionnaire, individual comments and remarks of those surveyed indicate a desire and tendency to wear the lap belt tight. However, the degree of tightness actually attained and maintained is questionable. As was previously shown in table XXVI, over one-third of those surveyed (regardless of population group) experienced difficulty tightening the lap belt, and only about 10% (refer to table XXIX) of those surveyed indicated selective manual loosening of the lap belt due to discomfort. In addition, the inability to sufficiently tighten the lap belt was one of the primary deficiencies cited in the MA-2 Integrated Torso Harness restraint system. Based upon the above, the lap belts are ultimately worn looser than intended.

83. Inflight Restraint Readjustment for Comfort. The only direct evidence of restraint adjustment in flight for comfort was associated with the lap belt (refer to paragraph 78). As previously shown in table XXIX, approximately 10% of those surveyed, regardless of population group, indicated that they normally loosen the lap belt for increased comfort. As indicated by the distributions of the lengths of time before lap belt readjustment (paragraph 78, table XXX), the 10% figure may be low. While 75% of those surveyed reported using the inertia reel locked only during takeoffs and landings (paragraph 79, table XXXI), no indication was given as to whether or not the reel is unlocked in flight for comfort or to facilitate required trunk movement.

84. Inflight Restraint Readjustment for Restraint. In addition to inflight readjustment of the lap belt for comfort, there is evidence of lap belt readjustment for restraint. However, the data indicate a retightening of the lap belt as opposed to a further tightening. With regard to the upper restraint system, the inertia reels are locked by the majority of aircrewmen (75%) during takeoffs and landings and left unlocked at other times. While there is a minimal (10%) use of the shoulder strap adjusters across all population groups, there is no indication as to whether this type of adjustment is for comfort, restraint, or both.

## Fleet Satisfaction and Acceptance of the Present Restraint Subsystems and the MA-2

85. Identification of Superior Systems and Subsystems. In general, slightly more than 20% of those surveyed considered some lap belt/adjuster configurations to be better than others as shown in table XXXVII. For those who had attributed aircraft control loss to deficiencies in the MA-2 Integrated Torso Harness, this figure increases to 41%. For each population group, table XXXVIII lists the expected (EXP) and observed (OBS) percentages of aircraft identified as having better lap belt/adjuster configurations than others. The quantity (QTY) column represents the number of pilots (out of a maximum of 982 responding to the Aircrew Personnel Restraint Questionnaire) who have had flight experience with the indicated aircraft (i.e., 221 of the 982 pilots surveyed have flown the A-6 aircraft). The numbers at the bottom of table XXXVIII give the total aircraft experience/number of superior aircraft citations for the indicated population group. For example, referring to table XXXVIII, those aircrewmen specially fitted for the MA-2 (Special Fit) have had flight experience in 1,929 aircraft, 154 (or 8%) of which were A-6's. This group cited 134 superior aircraft with respect to the lap belt/adjuster configuration, 38

(or 28%) of which were A-6's. As can be seen (refer to notation * in table XXXVIII), the observed percentages of the A-6, F-14, and AV-8 aircraft consistently exceed the percentages expected solely on the basis of aircraft type occurrence. All other things being equal, this tends to indicate that the lap belt/adjuster configurations of these particular aircraft are better than others.

Table XXXVII

Opinion of Population Groups Regarding Superior Lap Belt/Adjuster Configuration

Questionnaire No. 13 - Do you consider any lap belt/adjuster configuration to be better than others?

| Population Group | Population Size | % Yes | % No | % Blank |
|---|---|---|---|---|
| All | 982 | 23 | 64 | 13 |
| No Control Loss | 495 | 21 | 67 | 12 |
| Loss, MA-2 Deficiency | 41 | 41 | 39 | 20 |
| Loss, No MA-2 Deficiency | 334 | 24 | 64 | 12 |
| Special Fit | 663 | 23 | 64 | 13 |
| No Special Fit | 316 | 22 | 63 | 15 |
| Head Canopy | 694 | 24 | 62 | 14 |
| No Head-Canopy | 286 | 19 | 69 | 12 |

Table XXXVIII

Observed Versus Expected Percentage Preference of
Lap Belt/Adjuster Configuration

| | | Population Group | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | All | | No Control Loss | | Loss, MA-2 Deficiency | | Loss, No MA-2 Deficiency | | Special Fit | | No Special Fit | | Head-Canopy | | No Head-Canopy | |
| | | % | | % | | % | | % | | % | | % | | % | | % | |
| Aircraft | Quantity | EXP | OBS | EXP | OBS | EXP | OBS | EXP | OBS | EXP | OBS | EXP | OBS | EXP | OBS | EXP | OBS |
| A-6 | 221 | 8 | 28* | 10 | 43* | 3 | 14* | 5 | 11* | 8 | 28* | 8 | 27* | 5 | 17* | 16 | 60* |
| F-14 | 58 | 2 | 24* | 2 | 19* | 1 | 21* | 2 | 36* | 2 | 23* | 3 | 27* | 2 | 30* | 1 | 8* |
| A-4 | 876 | 31 | 11 | 32 | 14 | 33 | 21 | 30 | 11 | 31 | 13 | 32 | 7 | 31 | 11 | 31 | 12 |
| F-4 | 405 | 14 | 11 | 12 | 10 | 12 | 7 | 15 | 18 | 15 | 12 | 14 | 10 | 17 | 13 | 8 | 8 |
| AV-8 | 18 | 1 | 8* | -- | 2 | 1 | 21 | 1 | 2 | 1 | 6* | 1 | 8* | 1 | 7* | 1 | 4 |
| A-7 | 241 | 8 | 6 | 8 | 5 | 13 | -- | 10 | 11 | 8 | 4 | 9 | 10 | 9 | 7 | 6 | 2 |
| T-38 | 48 | 2 | 3 | 1 | 2 | 3 | -- | 2 | 2 | 2 | 4 | 1 | -- | 2 | 4 | 1 | 2 |
| T-2 | 475 | 17 | 2 | 19 | 1 | 17 | 8 | 15 | -- | 17 | 1 | 16 | 3 | 15 | 2 | 21 | -- |
| Others | 482 | 17 | 7 | 16 | 4 | 17 | 8 | 20 | 9 | 16 | 8 | 16 | 7 | 18 | 9 | 15 | 4 |
| Experience/ Citations | | 2824/193 | | 1358/88 | | 136/14 | | 899/55 | | 1929/134 | | 885/59 | | 2068/142 | | 751/50 | |

86. Desire for Improved Systems and Subsystems. There were strong indications across all population groups for improved restraint. This was most evident among those aircrewmen who had experienced aircraft control loss, especially those attributing the loss to deficiencies in the MA-2. The desire for improved restraint was freely and openly expressed in the individual remarks of those surveyed, some of considerable length. The inability to sufficiently tighten the lap belt appears to be the primary restraint concern of aircrewmen at this time. The majority of those surveyed felt that powered lap belt tightening would also be beneficial and desirable, as indicated by the data shown in table XXXIX.

87. MA-2 Restraint Adequacy. The majority of those aircrewmen who had attributed loss of aircraft control to deficiencies in the MA-2 Integrated Torso Harness rated the system as being inadequate. No majority of any other cross-section of those surveyed could be found that considered the MA-2 inadequate. Over 70% of all other population groups of special interest rated the MA-2 system as being adequate as shown in table XL. However, as previously noted in paragraph 73, many of these individuals qualified their opinion of the MA-2 by highlighting deficiencies in the system or by noting the absence of any alternative systems.

Table XXXIX

Use of Powered Lap Belt Tightening for Preejection Positioning

Questionnaire No. 32 - Do you feel that powered lap belt tightening in addition to a ballistic inertia reel for preejection positioning would be desirable?

| Population Group | Population Size | % Yes | % No | % Blank |
|---|---|---|---|---|
| All | 982 | 56 | 35 | 9 |
| No Control Loss | 495 | 56 | 36 | 8 |
| Loss, MA-2 Deficiency | 41 | 63 | 27 | 10 |
| Loss, No MA-2 Deficiency | 334 | 51 | 39 | 10 |
| Special Fit | 663 | 57 | 34 | 9 |
| No Special Fit | 316 | 54 | 37 | 9 |
| Head-Canopy | 694 | 58 | 33 | 9 |
| No Head-Canopy | 286 | 52 | 40 | 8 |

Table XL

Population Group Rating of the Adequacy of the MA-2 to Provide Restraint

Questionnaire No. 30 - Do you consider the MA-2 integrated restraint configuration an adequate restraint system?

| Population Group | Population Size | % Yes | % No | % Blank |
|---|---|---|---|---|
| All | 982 | 79 | 18 | 3 |
| No Control Loss | 495 | 80 | 16 | 4 |
| Loss, MA-2 Deficiency | 41 | 46 | 51 | 3 |
| Loss, No MA-2 Deficiency | 334 | 85 | 12 | 3 |
| Special Fit | 663 | 81 | 16 | 3 |
| No Special Fit | 316 | 73 | 22 | 5 |
| Head-Canopy | 694 | 74 | 22 | 4 |
| No Head-Canopy | 286 | 90 | 8 | 2 |

Aircrew Personnel Restraint Questionnaire Summary

88. Analysis of the Aircrew Personnel Restraint Questionnaire supports the General Conclusions of this study. Questionnaire responses clearly indicate that the inability to maintain a securely-tightened lap belt (during maneuvers and in adverse aircraft attitudes and environments) tend to force the pilot off the seat and away from the controls.

89. Questionnaire data did not confirm the conclusion that the F-14 and T-2 aircraft have the greatest reportage of overall restraint problems indicating that adequate restraint is more apt to be a problem in A-4 and A-7 aircraft and less apt to be a problem in A-6, F-14, and AV-8 aircraft. It should be noted, however, that the sample size of the questionnaire data for the latter two aircraft was extremely small. Of the 982 questionnnaire responses, 58 aircrewmen indicated experience with the F-14 aircraft and 18 of the 982 showed flight experience with the AV-8 aircraft. With respect to aircraft no longer in use or used only on a limited basis, the questionnaire tends to confirm the conclusion that restraint problems were minimal with respect to the F-9 aircraft.

90. As a final point it should be noted that the analysis of the Aircrew Personnel Restraint Questionnaire failed to reveal any particular characteristic (e.g., height, weight, MA-2 torso size, special fitting, etc.) that would directly correlate with restraint problems. This would indicate that restraint problems are equipment-related and further highlights the need for appropriate design specification requirements.

Utilization of the Enclosed Draft Specification

91. Based upon the findings outlined in the report and the task requirement to delineate restraint design requirements, an initial draft of a proposed specification has been prepared and is presented as appendix P. Although there are a number of unknowns influencing design, the areas of these unknowns have been identified such that a design procurement could be initiated. Contractors would be required to identify proposed efforts for ascertaining the necessary design information and to obtain procuring activity concurrence with the proposed investigative plans and approaches prior to commencing the design efforts. Procurement could be multipart, assuring satisfactory completion of all investigations and analysis prior to obtaining procuring activity permission to proceed with restraint system design efforts. The current MA-2 specification (MIL-H-1908) appears inadequate, based upon the deficiencies identified in this report. The specification should be replaced with a specification that takes into account the findings of this investigation. The new specification should ensure achievement of a good resolution of the two-sided problem of providing sufficient aircrew mobility to effectively perform operational tasks throughout the flight regime/mission envelope while providing adequate restraint to ensure ability to perform those tasks necessary to control or regain control of aircraft under adverse flight situations.

# CONCLUSIONS

## GENERAL

92. Within the scope of this study, the MA-2 Integrated Torso Harness in present use in U.S. Naval tactical jet aircraft fails to provide adequate restraint, particularly against -Gz, even when properly fitted and used. The inability to maintain a securely tightened lap restraint degrades the pilot's ability to position and hold controls during departures, spins, and various aerobatic/air combat maneuvers to the extent that, in several cases, the restraint inadequacy contributed to the loss of aircraft that might have been saved; resulted in the fatalities of pilots who might otherwise have survived; seriously degraded egress capabilities; resulted in severe psychological distress, imparting a sense of detachment from the aircraft; and increased the risk of aircrew injury.

## SPECIFIC

### MEDICAL OFFICER'S REPORTS

93. Inadequate restraint contributed to the loss of at least four aviators (paragraph 17).

94. Inadequate restraint possibly contributed to the loss of 16 aircraft (paragraph 18).

95. The failure to utilize a premaneuver checklist to insure restraint harness locked during high performance testing of an aircraft may have contributed to the loss of at least two aircraft (paragraph 14.d).

96. Injuries due to "ejection forces" were not amenable to a breakdown into areas of poor restraint, yet it would appear that many aviators are receiving spinal injuries as a result of poor seat/man contact, which could be attributed to inadequate restraint at the moment of ejection (paragraph 24).

97. Unpowered inertia reels were associated with a higher incidence of injuries than were powered inertia reels (paragraph 25).

98. Damage or failure of the interface between the Rigid Seat Survival Kit and the MA-2 Integrated Torso Harness compromised aircrew survivability through loss of survival equipment (paragraph 13.a).

99. The SV-2A survival vest designed for carrying/stowing items of personal survival equipment is not meeting the operational needs of the aircrewman (paragraph 13.b).

100. Difficulty in obtaining a properly fitted torso harness degrades the MA-2, not only as a parachute harness (allowing greater opening shock effect) but also as a cockpit restraint since it prevents a man with a small girth from fully tightening his lap belt (paragraph 13.c).

101. The inability to maintain a securely tightened lap restraint degrades the pilot's ability to control his aircraft during departures, spins, and adverse maneuvers (paragraph 14.a).

102. The single lap belt concept presently integrated into the MA-2 torso harness allows the aviator to float out of his seat, leaving him hanging in his straps, seriously degrading his ability to effectively apply corrective inputs during uncontrolled flight, to eject, or to sustain ground impact (paragraphs 16, 17, and 18).

103. The decision of a pilot to fly with unlocked shoulder fittings indicates complacency on the part of the pilot, lack of training, lack of enforcement in proper equipment use, or a system that is overly restrictive, degrading the pilot mobility necessary for successful air combat maneuvering (paragraph 14.b).

104. The decision of a pilot to fly with an unlocked inertia reel suggests that the inertia reel design is inadequate because of inadequately specified design requirements for resolving the dichotomous needs for upper torso restraint and mobility (paragraph 14.d).

105. The present restraint system features <u>do not</u> provide ready transition from exocraft configuration to optimal in-cockpit restraint (without adjusting the restraints in the cockpit), minimal nuisance during certain phases of flight, and instantly available restraint during all phases of flight (paragraph 20).

106. Among current inventory U.S. Navy aircraft, the greatest reported overall restraint problems are by aircrewmen in the F-14 and T-2 aircraft, while the least number of problems are being reported by aircrewmen in the F-4 aircraft (paragraph 26).

107. Among aircraft no longer in use or used only on a limited basis, the F-9 appears to be the focus of the largest number of restraint problems and the A-5 has the least reported number of restraint problems (paragraph 26).

## LABORATORY CONCLUSIONS

108. Head displacement, off-seat displacement, and torso stretch, as measured in this laboratory study, indicate the following (paragraphs 36 and 37):

a. The present MA-2 lap belt subsystem, even when adjusted unnaturally tight, allows significant off-seat displacement.

b. A significant reduction in off-seat displacement (and, therefore, overall body movement) can be achieved by improving pelvic restraint.

c. The MA-2 Integrated Torso Harness does not effectively inhibit torso stretch. Therefore, even a good lap belt restraint system may permit aircrew contact with cockpit canopies in many aircraft unless measures are taken to constrain spinal stretch in the torso.

d. Failure to design restraints to counter both off-seat displacement and torso stretch results in restraint systems which will not provide adequate restraint.

109. Shoulder displacement exceeds head displacement, indicating some form of independent shoulder motion (paragraph 39).

110. The significant loss of effective foot reach when using the MA-2 could result in less than optimal rudder control input to the aircraft, erratic control inputs, or reduced perception of the control inputs (paragraph 40).

111. The lack of significant correlations in these studies of loss of effective reach is due to the multiplicity of factors which affect functional loss (paragraph 41).

112. No difficulty is encountered in properly adjusting the torso harness chest strap while seated in a variety of fighter and attack aircraft (paragraph 47).

113. The parachute harness portion of the MA-2 tends to interfere with optimal tightening of the lap belt (paragraph 49).

114. The restraint effectiveness of the MA-2 was exceeded by all other combinations of experimental restraints used in this study which supports the feasibility of improving aircraft restraint systems (paragraphs 36.b and 50).

115. Under laboratory conditions during backward rotations, the lap belt twisted in such a way as to cause the Mini-Koch quick release adapter to create an inordinate amount of pressure and pain on the bony prominence of the hips (when under -Gz) which could contribute to functional loss (paragraph 51).

116. On the RSSK-8A seat pan, the geometry of the lower restraint subsystem appears to contribute to off-seat displacement (paragraph 52).

117. As demonstrated under laboratory conditions, no -Gz restraint is offered by the upper torso restraint portion of the MA-2 Integrated Torso Harness (paragraph 53).

118. The free play that exists at the upper restraint portion of the MA-2 may mask perception of the status of the inertia reel lock during -Gx and may induce the aircrewman to experiment with the locking control (paragraph 53).

119. Nylon keepers on the lower restraint subsystems may be interfering with proper adjustment of the lap belt, reducing restraint effectiveness (paragraph 54).

120. Gradual slackening of the lap belt which may occur during flight reduces restraint effectiveness (paragraph 55).

121. Inability to vectorily apply sufficient force to fully tighten the lap belt (as seen in the RSSK-8A) degrades restraint effectiveness (paragraph 56).

122. Binding and jamming of the nylon webbing used for adjusting both the upper and lower restraint portions of the MA-2 degrades the restraint effectiveness of the MA-2 (paragraph 57).

123. The Koch-type upper torso quick-release connectors are prone to inadvertent opening, resulting in inadequate attachment to the parachute and degradation of -Gx restraint (paragraph 58).

124. Data collected during this study concerning the feet and thighs are inconclusive (paragraph 59).

125. The effect of restraining the shoulders is a restriction of functional ability during certain flight conditions (paragraph 60).

AIRCREW PERSONNEL RESTRAINT QUESTIONNAIRE CONCLUSIONS

126. Questionnaire data did not confirm the conclusion that the F-14 and T-2 aircraft have the greatest reportage of overall restraint problems indicating that adequate restraint is more apt to be a problem in A-4 and A-7 aircraft (paragraph 89).

127. Restraint problems are equipment-related, highlighting the need for appropriate design specification requirements (paragraph 90).

128. The Aircrew Personnel Restraint Questionnaire results support all other general conclusions of this study (paragraph 88).

SPECIFICATION CONCLUSION

129. The current MA-2 specification appears inadequate, based upon the observed MA-2/MA-2P deficiencies, and should be replaced with a specification that takes into account the findings of this investigation (paragraph 91).

# RECOMMENDATIONS

## GENERAL

130. Design requirements for aircrew personnel restraint systems should be reevaluated for the purpose of improving restraint effectiveness in all flight regimes and emergency egress situations, compatibility with personal survival equipment, and aircrew comfort and mobility.

## SPECIFIC

131. Provide standardized references for supplying to Medical Officer's Reports correct nomenclature describing man-mounted survival, restraint, and parachuting equipment (paragraph 13.a).

132. Remove and replace the MS 22019 lap belt friction adapters with an item which precludes slippage or malfunction (paragraphs 14.a and 55).

133. Provide positive indication to the crewman that the upper restraint parachute release fitting (Koch type) is properly locked (paragraphs 14.b and 58).

134. Touch code the inertia reel locking handle so that it is more easily and readily tactily identifiable as being in the "LOCKED" or "UNLOCKED" positions (paragraphs 14.d and 53).

135. Eliminate the problems associated with the pressure caused by the lap belt fittings upon the bony prominences of the hips, perhaps by attaching padding between the fittings and the nylon panels of the MA-2 (paragraph 51).

136. Utilize as a safety precaution a premaneuver checklist (which includes "HARNESS LOCKED") prior to initiating each flight maneuver (paragraph 14.d).

137. Develop and pursue an immediate modification to the MA-2 Integrated Torso Harness to reduce off-seat travel during inflight -Gz acceleration to an acceptable level (paragraphs 16, 17, 18, 36, and 37).

138. Research and develop restraint subsystem features that insure adequate seat/man contact and minimize head displacement during -Gz acceleration (paragraph 37).

139. Reevaluate the design, location, and usage of the lap belt keeper to determine the possible advantages or disadvantages of modification removal (paragraph 54).

140. Review training programs which indoctrinate pilots in the use of the MA-2 and its related subsystems. Task squadron safety officers with the enforcement of proper usage of the MA-2, related subsystems, and man-mounted survival equipment in order to reduce the incidence of misuse of equipment, use of unauthorized equipment, and nonstandard modifications of equipment (paragraphs 13 and 14).

141. Stress greater attention to human factors principles and interactions among equipment, including the relationship between man-mounted equipment and the cockpit design, into equipment and cockpit designs in the future (paragraphs 13 and 14).

142. Establish functional loss as an element of evaluation in all future restraint design evaluations, seat evaluations, and aircrew stations where restraint systems are an integral part of the system being evaluated (paragraph 42).

143. Conduct a comparative evaluation of the U.S. Air Force partially integrated torso harness against the U.S. Navy MA-2 Integrated Torso Harness to determine the relative merits of a restraint system which is not attached to the torso harness (paragraph 46).

144. Investigate the problems associated with the geometry of the lower restraint subsystem with respect to its contribution to overall body movement under -Gz (paragraph 52).

145. Review the biomechanical requirements for restraint adjustment and attachment so that the forces required to adequately adjust the restraint are easily met by the aircrewman (paragraph 56).

146. Perform studies to determine the significance of visceral shift and other nonmechanical factors which would adversely affect restraint performance (paragraph 55).

147. Conduct a research effort to determine the cause, magnitude, and mechanics of spinal stretch during -Gz and methods for constraining such stretch (paragraph 38).

148. Research and develop restraint features which allow the aircrewman to walk, climb, and run while wearing the harness, unrestricted by the harness, and which also provide ready transition from exocraft to optimal endocraft adjustment (paragraphs 23 and 47).

149. Research and develop restraint system and subsystem features which provide the aircrewman with zero interference or nuisance during all phases of flight while providing instantly available maximum restraint upon demand (paragraphs 20 and 22).

150. Investigate textiles, textile designs, usages, methods of joining, and other state-of-the-art aspects of textile technology which might apply to the manufacture of restraint equipment with emphasis on susceptibility to damage or stitching failure (paragraph 13.a).

151. Investigate the feasibility of providing fewer basic sizes of torso garments, utilizing multiple-point adjustment features (paragraph 13.c).

152. Conduct an in-depth comparative investigation by a human factors engineering team to analyze and diagnose the problems and merits associated with specific aircraft restraint systems, to identify those factors which make one restraint system superior to another, and, thereby, to generate improved restraint subsystem specifications (paragraph 26).

153. Review aircrew needs for mobility and upper torso restraint, emphasizing all phases of flight, and initiate efforts directed at providing restraint systems and subsystems that meet these needs (paragraphs 14.b and 14.d).

154. Conduct additional studies to determine the merits of restraining various nontorso portions of the body and of restraining various sections of the torso during adverse accelerative exposure (paragraphs 59 and 60).

155. Utilize appendix P as a baseline for future drafts of improved restraint system specifications or directly as a tool to acquire improved aircrew restraint systems which better meet the full spectrum of aircrew needs.

AD-A058 995 NAVAL AIR TEST CENTER PATUXENT RIVER MD F/G 1/3

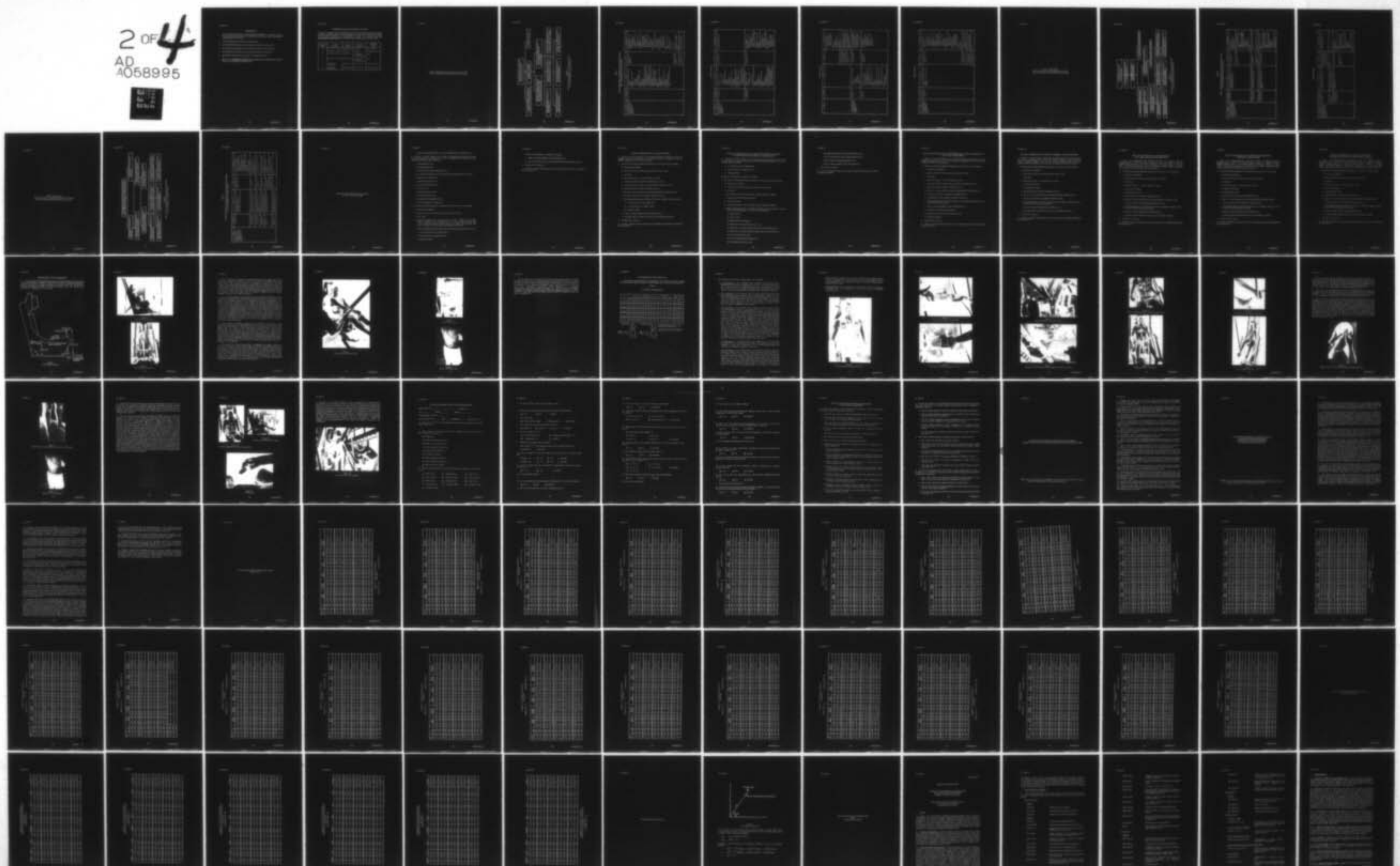
AIRCREW PERSONNEL RESTRAINT SUBSYSTEMS DEFINITION OF DEFICIENCI--ETC(U)

AUG 78 R BASON, J ETHEREDGE

UNCLASSIFIED NATC-SY-28R-78 NL

2 OF 4

AD A058995



## REFERENCES

1. NAVAIRSYSCOM AIRTASK A53153120535/6531000001 of 1 Apr 1976, Aircrew Personnel Restraint Subsystems, Definition of Deficiencies and Requirements, and Evaluation of Concepts.

2. ACEL Anthropometry of Naval Aviators, 1964.

3. NAVAIRTESTCEN Report of Test Results SA-73R-77 of 6 Oct 1977.

4. NAVAIRTESTCEN Report of Test Results SA-22R-76 of 14 Apr 1976.

5. NAVAIRTESTCEN Report of Test Results FT-8R-72 of 4 Feb 1972.

6. OPNAVINST 4790.2A, Vol. II, Chapter 7, Paragraph 1701(c)1.

7. Kirk, R. E.; Experimental Design: Procedures for the Behavioral Sciences; Brooks/Cole Publishing Company, 1968.

## DEFINITION OF GRAVITATIONAL VECTORS

In order to facilitate future inquiries into the effects of gravitational acceleration on flight, standard terms are used throughout the report and in the body of data. The following definitions of gravitational vectors are derived from The Bioastronautics Data Book (NASA SP-3006, Second Edition, Parker & West, Ed.).

| Physiological Standard | Acceleration Descriptive | Vernacular Descriptive | Physiological Descriptive | Equivalent Terrestrial Posture |
|---|---|---|---|---|
| + Gz | Footward Acceleration | Eyeballs Down | Positive G | Erect or Seated |
| - Gz | Headward Acceleration | Eyeballs Up | Negative G | Suspended upside-down |
| + Gx | Forward Acceleration | Eyeballs In | Transverse A-P G, Supine G, Chest to Back G | Supine |
| - Gx | Backward Acceleration | Eyeballs Out | Transverse P-A G, Prone G, Back to Chest G | Prone |
| + Gy | Right Lateral Acceleration | Eyeballs Left | Left Lateral G | Laying on Right Side |
| - Gy | Left Lateral Acceleration | Eyeballs Right | Right Lateral G | Laying on Left Side |

LOGIC TREE/FMEA FOR AIRCREWMAN FLYING
WITH AN INADEQUATE RESTRAINT SYSTEM

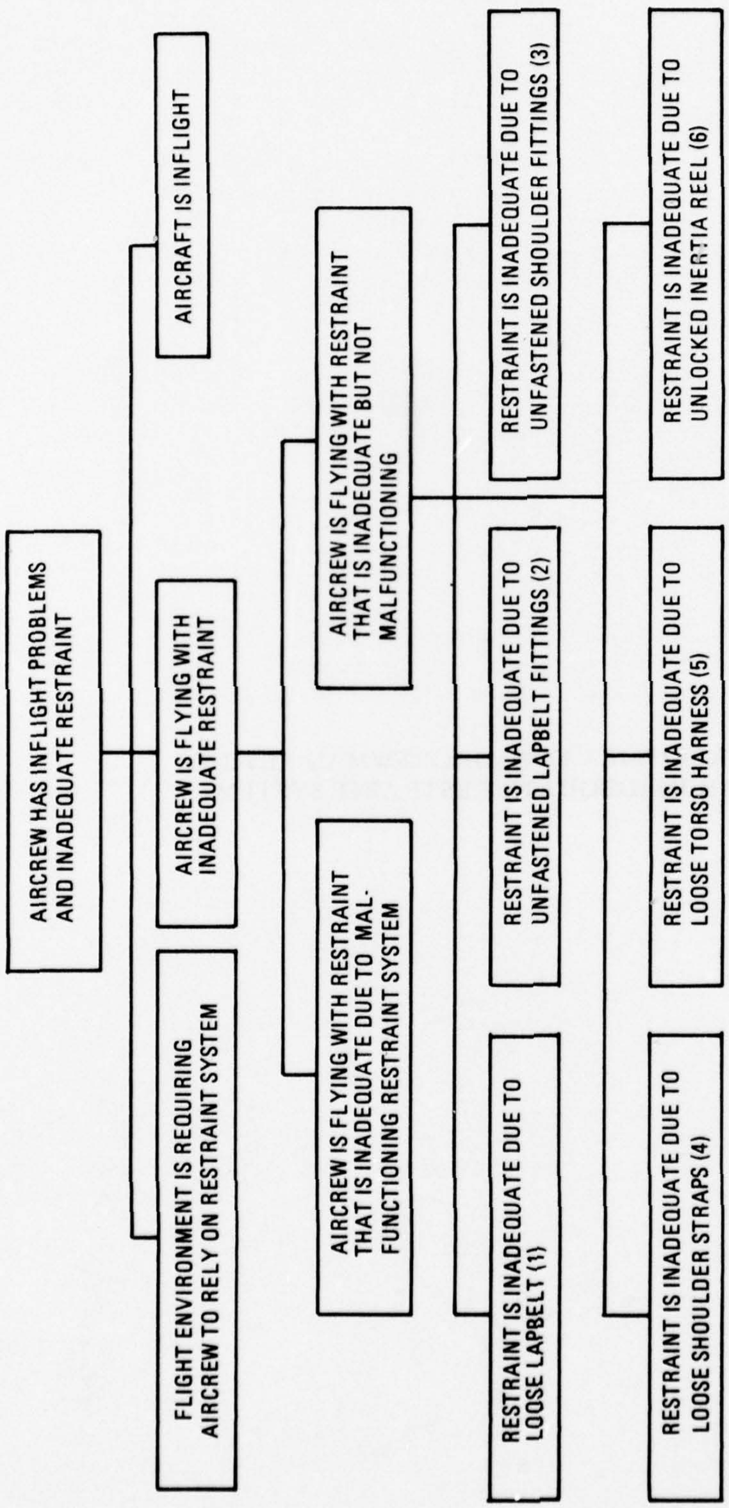



Figure 1
Logic Tree for Analysis of Aircrewman Flying with an Inadequate Restraint System

## Table I

### Failure Mode Effects Analysis for Aircrewman Flying with an Inadequate Restraint System

| Mode | Mechanism | Cause | Effect | Consequences |
|---|---|---|---|---|
| Aircrewman flying with a restraint system that is inadequate but not malfunctioning or defective | . Loose lap belt (1) | . Normally flies with loose lap belt<br>  . Comfort<br>  . Mobility<br>. Neglected to tighten lap belt<br>  . Forgot<br>    . Distracted<br>    . In a hurry<br>  . Did not know how<br>    . Lack of training<br>. Lap belt would not fully tighten<br>  . Binding<br>  . Bottomed out<br>. Anthropometry<br>  . Binding/jamming of restraint fittings between subject and side of seat<br>  . Used up straps to where ends are not accessible/graspable<br>  . Cannot effect leverage due to geometric constraints of seat and cockpit<br>. Restraint design<br>  . Design angle/vector force would allow subject to lift off seat<br>  . Lap belt keeper prevented full adjustment<br>. Slippage<br>  . Friction adapter in contact with lap belt keeper<br>. In-flight adjustment<br>  . Comfort<br>  . Accommodate visceral distention<br>. Visceral shift<br>. Fabric bulk shift<br>. Interference by flight gear<br>  . Contact between fittings and flight gear | . "Hanging in Straps" during zero or negative G | . Physical Impairment<br>  . Degraded ability to reach flight controls<br>    . Poor weapons delivery<br>    . Poor ACM, DCM<br>    . Degraded ability to effect recovery<br>    . Inadvertent/incorrect control inputs<br>  . Degraded ability to see flight instruments<br>    . Inability to accurately assess flight condition<br>    . Poor weapons delivery<br>    . Poor ACM, DCM<br>    . Degraded ability to effect recovery<br>    . Inadvertent/incorrect control inputs<br>. Sensory impairment<br>  . Disorientation<br>    . Unable to accurately assess flight condition<br>    . Inadvertent/incorrect control inputs<br>. Increase anxiety/panic<br>  . Mental degradation<br>    . Inability to accurately assess flight conditions<br>    . Premature ejection<br>. Injury<br>  . Primarily seat slap during boost<br>. Damage to helmet/visor<br>. Loss of aircraft<br>. Loss of man |
| | | | . Submarining during positive G (including ejection) | . All of above<br>. Increased risk of vertebral injury due to poor vertebral alignment |
| | | | . Poor body position for initiating ejection | . Difficulty initiating escape<br>. Unable to initiate escape |

Table I (Cont'd)

| Mode | Mechanism | Cause | Effect | Consequences |
|---|---|---|---|---|
| Aircrewman flying with a restraint system that is inadequate but not malfunctioning or defective | . Lap belt fittings not fastened (2) | . Pilot did not fasten lap belt fittings<br>. Forgot<br>. In a hurry to takeoff<br>. Preparing to egress<br>. Distracted<br>. Normally flies with mini-Kochs unfastened<br>. Comfort<br>. Greater mobility<br>. Poor habit<br>. Pilot released Kochs in flight<br>. Comfort<br>. More mobility<br>. Accommodate visceral distention<br>. Lap belts fittings inadvertently unfastened in flight<br>. Lap belt fittings not securely locked<br>. Foreign body inside locking bar which allows lap belt fitting to snap in but does not lock | . Effects the same as for loose lap belt | . Consequences same or more severe as for loose lap belt |
| | . Shoulder fittings not fastened (3) | . Pilot did not fasten fittings<br>. Forgot<br>. Distracted<br>. In a hurry to takeoff<br>. Preparing for egress<br>. Normally flies with fittings unfastened<br>. Comfort<br>. Mobility<br>. Visual tracking<br>. Anti-fatigue measure<br>. Poor habit<br>. Pilot released fittings in flight<br>. Comfort<br>. Mobility<br>. Visual tracking<br>. Anti-fatigue measure<br>. Fittings become unfastened in flight<br>. Not properly secured-cover/locking pin in down position gives false sense that fittings are locked<br>. Inadvertent unlocking by flight gear | . Pilot pitches forward during positive G | . Physical impairment<br>. Degraded ability to reach flight control<br>. Poor weapons delivery<br>. Poor ACM, DCM<br>. Degraded ability to effect recovery of departed aircraft<br>. Inadvertent/incorrect control inputs<br>. Degraded ability to see flight instruments<br>. Inability to accurately assess flight condition<br>. Poor weapons delivery<br>. Poor ACM, DCM<br>. Degraded ability to effect recovery of departed aircraft<br>. Sensory impairment<br>. Disorientation<br>. Inability to accurately assess flight condition<br>. Inadvertent/incorrect control inputs |

Table I (Cont'd)

| Mode | Mechanism | Cause | Effect | Consequences |
|---|---|---|---|---|
| | | | | . Increased anxiety/panic<br>. Mental degradation<br>. Inability to accurately assess flight conditions<br>. Premature ejection<br>. Injury<br>. Non-eject<br>. Landing eject<br>. Damage to helmet/visor<br>. Loss of aircraft<br>. Loss of man |
| | | | . Pilot pitched laterally | . Same as above |
| | | | . Poor body position for initiating ejection | . Difficulty initiating ejection<br>. Unable to initiate ejection |
| | | | . Poor body position for ejection | . Strike cockpit during ejection<br>. Impair system operation/ trajectory |
| Aircrewman flying with a restraint system that is inadequate but not malfunctioning or defective | . Shoulder straps loose (4) | . Pilot neglected to tighten straps<br>. Forgot<br>. In a hurry<br>. Distracted<br>. Did not know how<br>. Lack of training<br>. Comfort | . Pilot pitched forward during positive G | . False sense that inertia reel unlocked and may inadvertently unlock it while resting<br>. Consequences same as for pilot pitched forward during positive G (see above) |
| | . Loose torso harness (5) | . Pilot wore torso harness that was too large<br>. Not measured properly<br>. Not measured at all<br>. Measured properly but proper size not available in store<br>. Harness modified for use with anti-exposure suit<br>. Pilot generally flies with loose torso harness<br>. Comfort<br>. Mobility<br>. Pilot loosened torso harness in flight<br>. Comfort<br>. Pilot did not tighten chest straps<br>. Comfort<br>. Unfamiliar with adjustment procedure<br>. Changes in Somatype<br>. Loss of weight<br>. Gain of weight sloppy readjustment | . Out of phase with aircraft induced oscillation | . Sensory impairment<br>. Disorientation<br>. Poor weapons delivery<br>. Poor ACM, DCM<br>. Degraded ability to accurately assess flight conditions<br>. Inadvertent/incorrect control inputs |

## Table I (Cont'd)

| Mode | Mechanism | Cause | Effect | Consequences |
|---|---|---|---|---|
| **Aircrewman flying with a restraint system that is inadequate but not malfunctioning or defective** | . Inertia reel does not lock automatically (6) | . G onset not sufficient to affect locking<br>. Rate of payout too slow to effect locking<br>. Inadvertent release of harness lock lever | . Pilot pitches forward during positive G loading or on arrestment | . Physical impairment<br>  . Degraded ability to reach flight controls<br>    . Poor weapons delivery<br>    . Poor ACM, DCM<br>    . Degraded ability to effect recovery<br>    . Inadvertent/incorrect control inputs<br>  . Degraded ability to see flight instruments<br>    . Inability to accurately assess flight conditions<br>    . Poor weapons delivery<br>    . Degraded ability to effect recovery<br>    . Inadvertent/incorrect control inputs<br>. Sensory impairment<br>  . Disorientation<br>    . Unable to accurately assess flight condition<br>    . Inadvertent/incorrect control inputs<br>. Increase anxiety/panic<br>  . Mental degradation<br>    . Inability to accurately assess flight condition<br>    . Premature ejection<br>. Injury<br>. Loss of aircraft<br>. Loss of man |
| | | | . Pilot pitched laterally during G loading | . Consequences same as for pilot pitched forward during positive G loading |
| | | | . Poor body position for initiating escape | . Difficulty initiating escape<br>. Unable to initiate escape |
| | | | . Poor body position for ejection loads | . Injury |

# LOGIC TREE/FMEA
# FOR ANALYSIS OF AIRCREWMAN EJECTING
# WITH AN INADEQUATE RESTRAINT SYSTEM

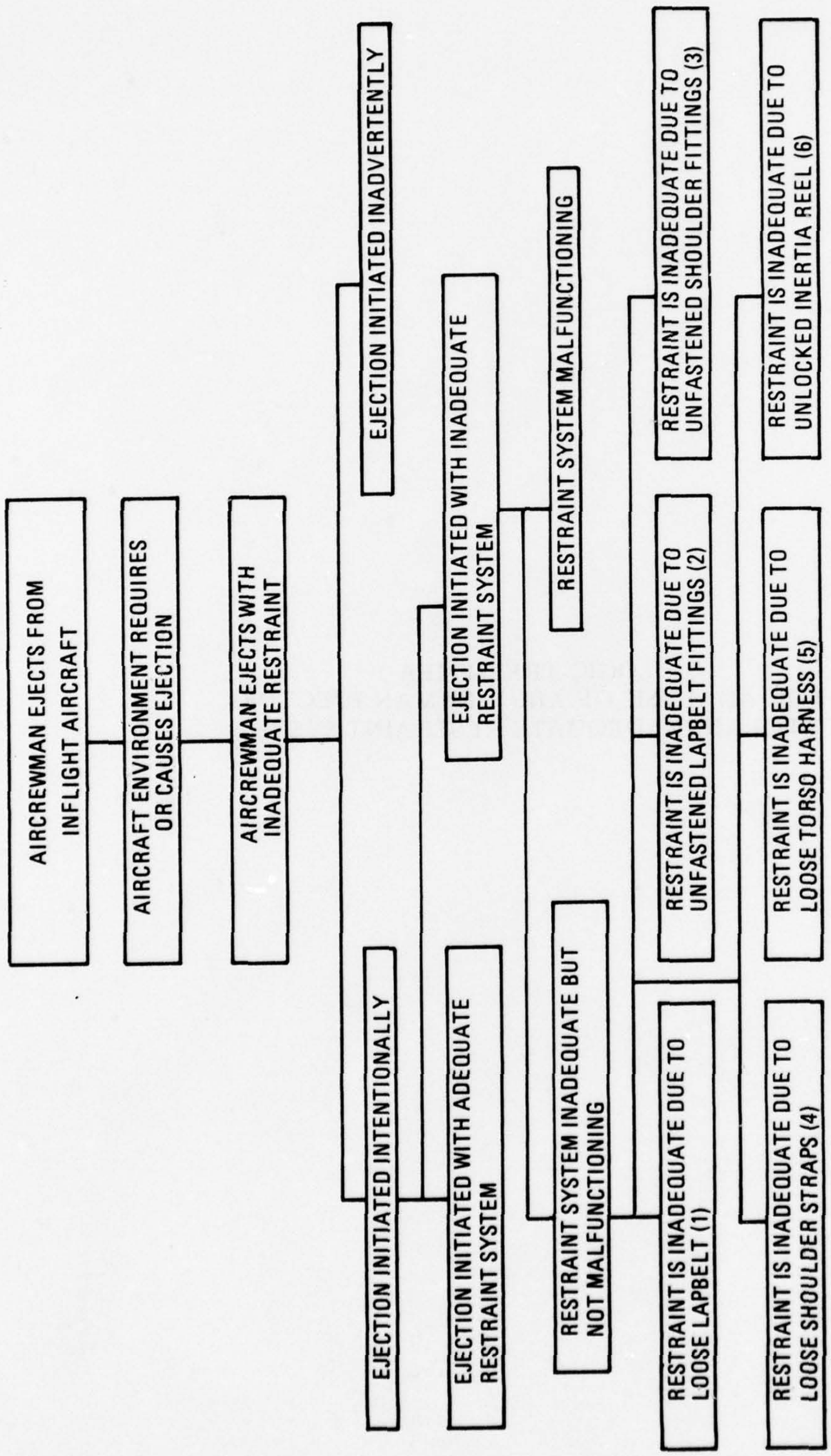



Figure 1
Logic Tree for Analysis of Aircrewman Ejecting
with an Inadequate Restraint System

Table I

Failure Mode Effects Analysis for Aircrewman Ejecting with an Inadequate Restraint System

| Mode | Mechanism | Cause | Effect | Consequences |
|---|---|---|---|---|
| Aircrewman ejects from aircraft with a restraint system that is inadequate but not malfunctioning or defective | . Loose lap belt (1) | . As previously described for aircrewman flying with loose lap belt<br>. Loosens under ejection load | . Poor body position for ejection | . Spinal injuries<br>. Leg/thigh injuries<br>. Injuries due to aircraft structural contact |
| | | | . Adverse shift in man-seat CG | . Unstable flight (tumbling)<br>. Reduced parachute opening height<br>. Reduced trajectory height<br>. Impaired man-seat separation<br>. Increased risk of parachute entanglement<br>. With ejectee<br>. With seat<br>. Increased risk of flail injuries |
| | . Lap belt fittings not fastened (2) | . As previously described for aircrewman flying with lap belt not fastened | . Poor body position for ejection<br><br>. Adverse shift in man-seat CG | . As described above for loose lap belt<br><br>. As described above for loose lap belt |
| | . Shoulder fittings not fastened (3) | . As previously described for aircrewman flying with shoulder fittings not fastened | . Pilot not attached to shoulder restraints | . Body inertia causes forward rotation<br>. Adverse shift in man-seat CG<br>. Reduced trajectory height<br>. Reduced parachute opening height<br>. Impaired man-seat separation<br>. Increased risk of parachute entanglement<br>. With ejectee<br>. With seat<br>. Potential body contact with aircraft structure |

Table I (Cont'd)

| Mode | Mechanism | Cause | Effect | Consequences |
|---|---|---|---|---|
| Aircrewman must eject with restraint system that is inadequate but not malfunctioning or defective | . Shoulder straps loose (4) | . As previously described for aircrewman flying with loose shoulder straps | . Potential incomplete haul-back of powered reel/full retraction does not produce full back position of man's torso | . Same as described above for shoulder fittings not fastened |
| | . Loose torso harness (5) | . As previously described for aircrewman flying with loose torso harness | None | None |
| | . Inertia reel does not fully retract aircrewman (6) | . Retraction force is not sufficient to overcome G force | . Poor body for ejection<br><br>. Body inertia causes forward rotation of body | . Spinal injuries<br>. Leg/thigh injuries<br>. Injuries due to aircraft structure contact<br>. Adverse shift in man-seat CG<br>  . Reduced trajectory height<br>  . Reduced parachute opening height<br>  . Impaired seat-man separation<br>  . Increased risk of parachute entanglement<br>    . With ejectee<br>    . With seat<br>. Increased risk of flail injuries<br>. Injuries due to aircraft structure contact |

LOGIC TREE/FMEA
FOR ANALYSIS OF AIRCREWMAN PARACHUTING
WITH AN INADEQUATE RESTRAINT SYSTEM

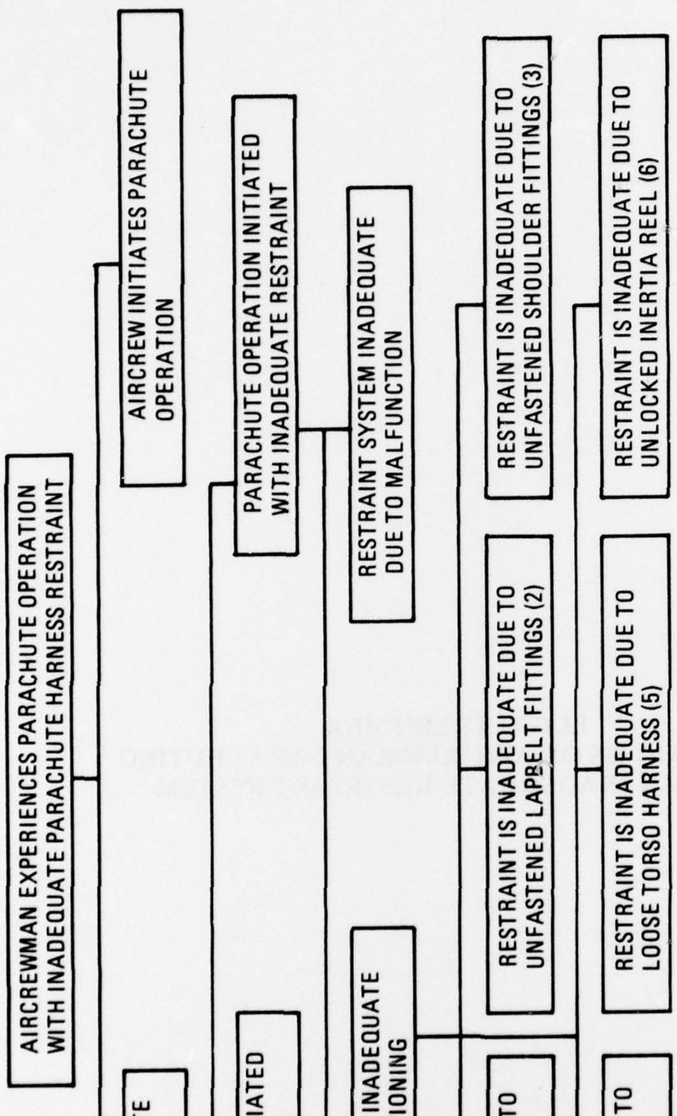



Figure 1
Logic Tree for Analysis of Aircrewman Parachuting
with an Inadequate Restraint System

Table I

**Failure Mode Effects Analysis for Aircrewman Parachuting with an Inadequate Restraint System**

| Mode | Mechanism | Cause | Effect | Consequences |
|---|---|---|---|---|
| **Aircrewman under parachute with a restraint system that is inadequate but not malfunctioning or defective** | . Loose lap belt (1) | . As previously described for aircrewman flying with loose lap belt<br>. Loosens under ejection load<br>. Loosens under parachute opening shock | . Structural failure under opening shock loads | . Poor retention of RSSK<br>. Difficulty reaching RSSK release handle because RSSK hanging too low<br>. Oscillating parachute because of low hanging RSSK<br>. Poor suspended risk may cause leg and other injuries on landing<br>. Loss of RSSK<br>. Loss of survival gear<br>. Opening shock injury |
| | . Lap belt fittings not fastened (2) | . As previously described for aircrewman flying with lap belt not fastened | . Loss of RSSK | . Loss of survival gear<br>. Injury due to collision with departing RSSK |
| | . Shoulder fittings not fastened (3) | . As previously described for aircrewman flying with shoulder fittings not fastened | . Pilot not attached to parachute | . "Excellent chance pilot will not live to fly again" |
| | . Shoulder straps loose (4) | . As previously described for aircrewman flying with loose shoulder straps | . Shoulder fittings travel | . Difficulty locating/reaching shoulder Kochs |
| | . Loose torso harness (5) | . As previously described for aircrewman flying with loose torso harness | . Torso harness will be pulled upward | . Opening shock injuries to scrotal area |
| | | | . Shoulder Kochs higher upon main lift webb | . Difficulty locating/reaching shoulder Kochs |
| | . Inertia reel does not lock (6) | . As previously described for aircrewman flying with unlocked inertia reel | None | None |

# INFORMATION REQUESTED FROM THE NAVAL SAFETY CENTER

TITLE OF COMPUTER RUN: TORSO GARMENTS MA-2 AND MA-2P

1. Provide a one-line listing of all aircraft accidents/incidents where MA-2 and MA-2P torso garment restraints were coded on OPNAV Form 3750/8E as being associated with one of the following:

a. Damaged Minor (05).

b. Damaged Major (06).

c. Restraint/Attachment Inadequacy (23).

d. Restraint/Attachment Not Used Properly for Maximum Protection (24).

e. Improper Use (Other) (25).

f. Unfamiliar with Use (26).

g. Discomfort/Bulkiness (32).

h. Poor Fit (33).

i. Material Deficiency (35).

j. Design Deficiency (36).

k. Nonstandard Configuration (41).

l. Prevented/Minimized Injury (44).

2. Provide the following additional information on the above one-line listing:

a. Identification Number.

b. Type of Aircraft (sort run by type aircraft in date order).

c. Seat Type.

d. Method of Escape; i.e., ejection, bailout, or other. Include all code/codes listed in OPNAV Form 3750/8F, Section 2; e.g., suspected bailout (B8) and/or standard emergency ground egress (CA). Note: Please include this type of coding in all enclosures requesting method of escape.

e. The following psychophysiological and environmental factors under Item 7:

(1) Acceleration Forces In Flight (701).

(2) Acceleration Forces Impact (702).

(3) Vibration (704).

Include factor importance and phase of mishap.

f. Degree of Injury (OPNAV Form 3750.8B, Item 1).

g. Aircraft Attitude at Time of Escape (OPNAV Form 3750/8F, Item 11).

3. Provide CY69 - present.

4. Provide a separate listing with the above information but include the MOR and general narrative.

TITLE OF COMPUTER RUN: LOSS OF CONTROL

1. Provide a one-line listing of all accidents/incidents involving ejection seat equipped aircraft, including the A-3, where the reason for escape was coded on OPNAV 3750/8F, Item 7, as "loss of control."

2. Provide the following additional information on the above one-line listing:

a. Identification Number.

b. Type of Aircraft (sort run by type aircraft in date order).

c. Seat Type.

d. Method of Escape - ejection, bailout, or other.

e. Anthropometric Data (OPNAV 3750/8D, Section IV).

f. Aircraft Attitude at Time of Escape (OPNAV 3750/8F, Item 11).

g. Egress Difficulties (OPNAV 3750/8F, Item 13).

h. Ejection - intent, initiated by, and method (OPNAV 3750/8G, *Item 8*).

i. Position of Ejection Seat (OPNAV 3750/8G, Item 9).

j. Psychophysiological and Environmental Factors (OPNAV 3750/8C, Item 7):

(1) Acceleration Forces In Flight (701).

(2) Acceleration Forces Impact (702).

(3) Vibration (704).

k. Degree of Injury (OPNAV Form 3750/8B, Item 1).

l. Restraints (MA-2 and MA-2P only) as listed in OPNAV 3750/8E.

3. Period CY69 - present.

4. Provide a separate listing with the above information but include the MOR and general narrative.

## TITLE OF COMPUTER RUN: ACCELERATION FORCES IN FLIGHT, ACCELERATION FORCES IMPACT, AND VIBRATION

1. Provide a one-line listing of all accidents/incidents involving ejection seat aircraft and the A-3 selected where any of the following environmental factors are coded on OPNAV 3750/8C:

   a. Acceleration Forces In Flight (701).

   b. Acceleration Forces Impact (702).

   c. Vibration (704).

Include factor importance and phase of mishap.

2. Provide the following additional information on the above one-line listing:

   a. Identification Number.

   b. Type of Aircraft (sort run by type aircraft in date order).

   c. Seat Type.

   d. Restraints (MA-2 and MA-2P only) as listed in OPNAV 3750/8E.

   e. Problems Associated with Restraints.

   f. Method of Escape.

   g. Aircraft Attitude at Time of Escape (Item 11, OPNAV 3750/8F).

   h. Egress Difficulties (Item 13, OPNAV 3750/8F) for Ground, Water, and Air before and during Egress for the Following Conditions:

      (1) Buffeting (01).

      (2) G Forces (02).

      (3) Hampered by Clothing (06).

      (4) Difficulty Releasing Canopy Latch (09).

      (5) Difficulty Locating/Reaching Normal Ejection Mechanism (11).

      (6) Difficulty Locating/Reaching Alternate Ejection Mechanism (12).

      (7) Face Curtain Problem (14).

      (8) Seat Pan-Firing Handle Problem (16).

      (9) Anthropometric Problem (29).

(10) Upper Extremities Hit Cockpit Structures (31).

(11) Lower Extremities Hit Cockpit Structures (32).

(12) Man Struck Canopy/Canopy Bow (33).

i. Degree of Injury (OPNAV Form 3750.8B, Item 1).

3. Period CY69 - present.

4. Provide a separate listing with the above information but include the MOR and general narrative.

TITLE OF COMPUTER RUN: ANTIEXPOSURE SUIT - TORSO GARMENT MA-2 AND MA-2P COMPATIBILITY

1. Provide a one-line listing of all accidents/incidents involving ejection seat equipped aircraft and the A-3 selected where an antiexposure suit was worn with the MA-2 or MA-2P torso garment.

2. Provide the following additional information on the above one-line listing:

a. Identification Number.

b. Type of Aircraft (sort by type aircraft in date order).

c. Seat Type.

d. Method of Escape - ejection, bailout, or other.

e. Aircraft Attitude at Time of Escape (OPNAV 3750/8F, Item 11).

f. Egress Difficulties (OPNAV 3750/8F, Item 13).

g. Ejection - intent, initiated by, and method (OPNAV 3750/8E, Item 8).

h. Position of Ejection Seat (OPNAV 3750/8E, Item 9).

i. Anthropometric Data (OPNAV 3750/8D, Section IV).

j. Psychophysiological and Environmental Factors (OPNAV 3750/8C, Item 7, Factors 701, 702, and 704).

k. Degree of Injury (OPNAV Form 3750/8B, Item 1).

l. Problems Associated with Restraints.

m. Problems Associated with Antiexposure Suit.

n. Reason for Escape.

3. Period CY69 - present.

4. Provide a separate listing with the above information but include the MOR and general narrative.

TITLE OF COMPUTER RUN: ROLLING, TUMBLING, AND/OR INVERTED

1. Provide a one-line listing of all aircraft accidents/incidents involving ejection seat aircraft, including the A-3, where the aircraft attitude at time of escape as coded on OPNAV 3750/8F, Item 11, was "rolling, tumbling, and/or inverted." Include additional attitude factors from Item 11 not used as selection criteria.

2. Provide the following additional information on the above one-line listing:

a. Identification Number.

b. Type Aircraft (post run by type aircraft in date order).

c. Seat Type.

d. Method of Escape - ejection, bailout, or other.

e. Reason(s) for Escape.

f. Anthropometric Data.

g. Egress Difficulties (OPNAV 3750/8F, Item 13).

h. Ejection - intent, initiated by, and method (OPNAV 3750/8G, Item 8).

i. Position of Ejection Seat (OPNAV 3750/8G, Item 9).

j. Psychophysiological and Environmental Factors (OPNAV 3750/8C, Item 7, Factors 701, 702, and 704, if present).

k. Degree of Injury (OPNAV Form 3750/8B, Item 1).

l. Restraints (MA-2 and MA-2P only) as listed in OPNAV 3750/8E.

3. Period CY69 - present.

4. Provide a separate listing with the above information but include the MOR and general narrative.

## TITLE OF COMPUTER RUN: NOSE DOWN SPIN, FLAT SPIN, AND/OR OSCILLATING SPIN

1. Select all accidents/incidents involving ejection seat equipped aircraft, including the A-3, where the aircraft attitude at time of escape, as coded on OPNAV 3750/8F, Item 11, was "nose down spin," "flat spin," and/or "oscillating spin." Provide this information on a one-line listing. Include additional attitude factors from Item 11 not used as selection criteria.

2. Provide the following additional information on the above one-line listing:

   a. Identification Number.

   b. Type Aircraft (post run by type aircraft in date order).

   c. Seat Type.

   d. Method of Escape - ejection, bailout, or other.

   e. Reason(s) for Escape.

   f. Anthropometric Data.

   g. Egress Difficulties (OPNAV 3750/8F, Item 13).

   h. Ejection - intent, initiated by, and method (OPNAV 3750/8G, Item 8).

   i. Position of Ejection Seat (OPNAV 3750/8G, Item 9).

   j. Psychophysiological and Environmental Factors (OPNAV 3750/8C, Item 7, Factors 701, 702, and 704, if present).

   k. Degree of Injury (OPNAV Form 3750/8B, Item 1).

   l. Restraints (MA-2 and MA-2P only) as listed in OPNAV 3750/8E.

3. Period CY69 - present.

4. Provide a separate listing with the above information but include the MOR and general narrative.

## TITLE OF COMPUTER RUN: DISINTEGRATION, MUSHING, UNKNOWN, AND/OR OTHER

1. Select all accidents/incidents involving ejection seat equipped aircraft, including the A-3, where the aircraft attitude at time of escape as coded on OPNAV 3750/8F, Item 11, was "Disintegration," "Mushing," "Unknown," and/or "Other." Provide this information on a one-line listing. Include additional attitude factors from Item 11 not used as selection criteria.

2. Provide the following additional information on the above one-line listing:

   a. Identification Number.

   b. Type Aircraft (post run by type aircraft in date order).

   c. Seat Type.

   d. Method of Escape - ejection, bailout, or other.

   e. Reason(s) for Escape.

   f. Anthropometric Data.

   g. Egress Difficulties (OPNAV 3750/8F, Item 13).

   h. Ejection - intent, initiated by, and method (OPNAV 3750/8G, Item 8).

   i. Position of Ejection Seat (OPNAV 3750/8G, Item 9).

   j. Psychophysiological and Environmental Factors (OPNAV 3750/8C, Item 7, Factors 701, 702, and 704, if present).

   k. Degree of Injury (OPNAV Form 3750/8B, Item 1).

   l. Restraints (MA-2 and MA-2P only) as listed in OPNAV 3750/8E.

3. Period CY69 - present.

4. Provide a separate listing with the above information but include the MOR and general narrative.

TITLE OF COMPUTER RUN: NOSE-UP, NOSE-DOWN, DEGREES, AND RIGHT BANK, LEFT BANK, DEGREES

1. Select all accidents/incidents involving ejection seat equipped aircraft, including the A-3, where the aircraft attitude at time of escape as coded on OPNAV 3750/8F, Item 11, was "Nose-Up," "Nose-Down," "Degrees," and "Right Bank," "Left Bank," Degrees." Provide this information on a one-line listing. Include additional attitude factors from Item 11 not used as selection criteria.

2. Provide the following additional information on the above one-line listing:

a. Identification Number.

b. Type Aircraft (post run by type aircraft in date order).

c. Seat Type.

d. Method of Escape - ejection, bailout, or other.

e. Reason(s) for Escape.

f. Anthropometric Data.

g. Egress Difficulties (OPNAV 3750/8F, Item 13).

h. Ejection - intent, initiated by, and method (OPNAV 3750/8G, Item 8).

i. Position of Ejection Seat (OPNAV 3750/8G, Item 9).

j. Psychophysiological and Environmental Factors (OPNAV 3750/8C, Item 7, Factors 701, 702, and 704, if present).

k. Degree of Injury (OPNAV Form 3750/8B, Item 1).

l. Restraints (MA-2 and MA-2P only) as listed in OPNAV 3750/8E.

3. Period CY69 - present.

4. Provide a separate listing with the above information but include the MOR and general narrative.

## DESCRIPTION OF TEST EQUIPMENT

1. An ejection seat CG determinator was procured from salvage and served as the test platform (figures 1 through 3). This device is capable of rigidly supporting an ejection seat and its occupant, rotating in the pitch mode. The platform has 360 deg of freedom of motion in this mode, allowing a seat and subject to be subjected to a loading of $\pm 1Gz$ or $\pm 1Gx$.

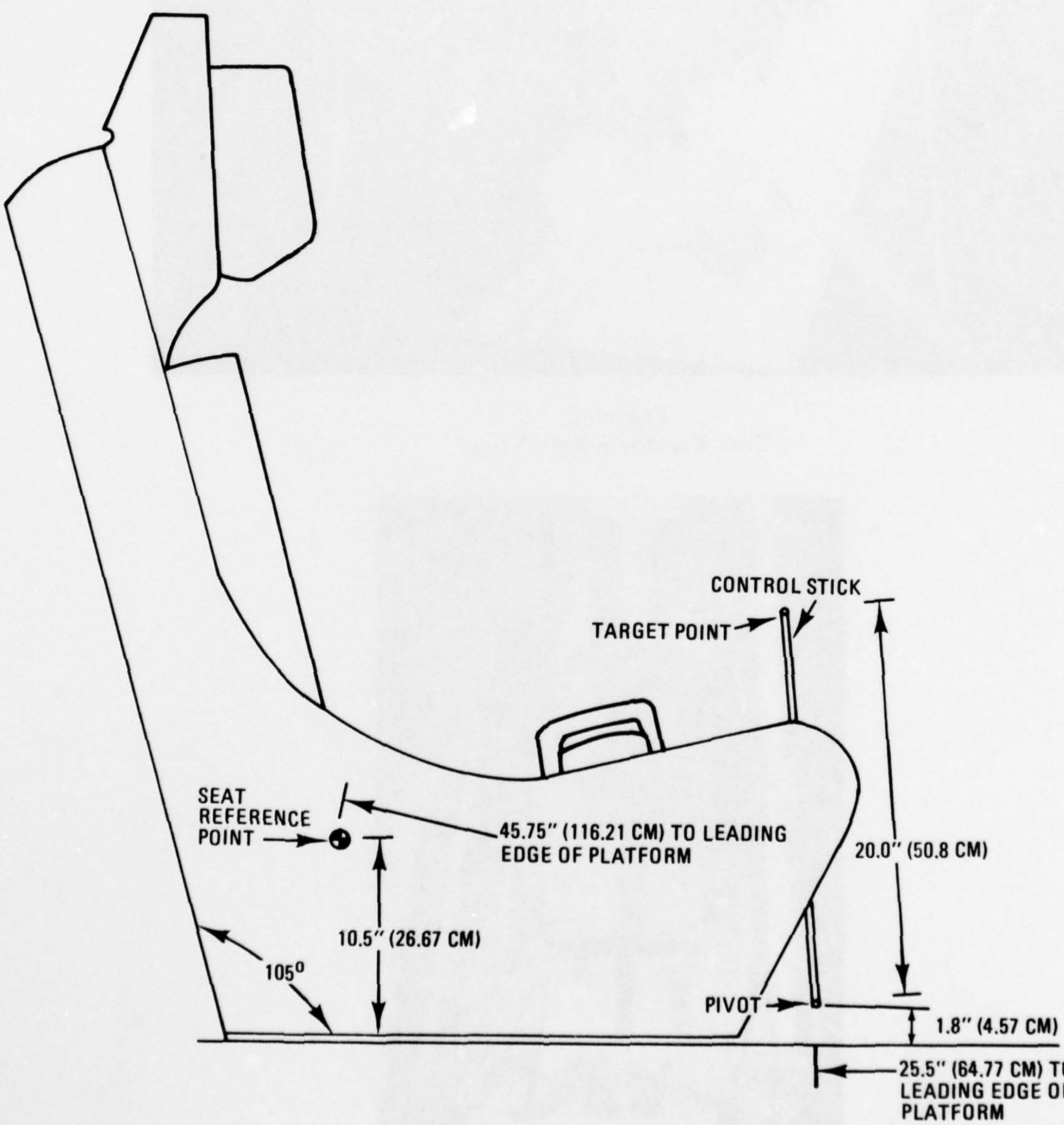



**Figure 1**
**Test Seat Dimensions**

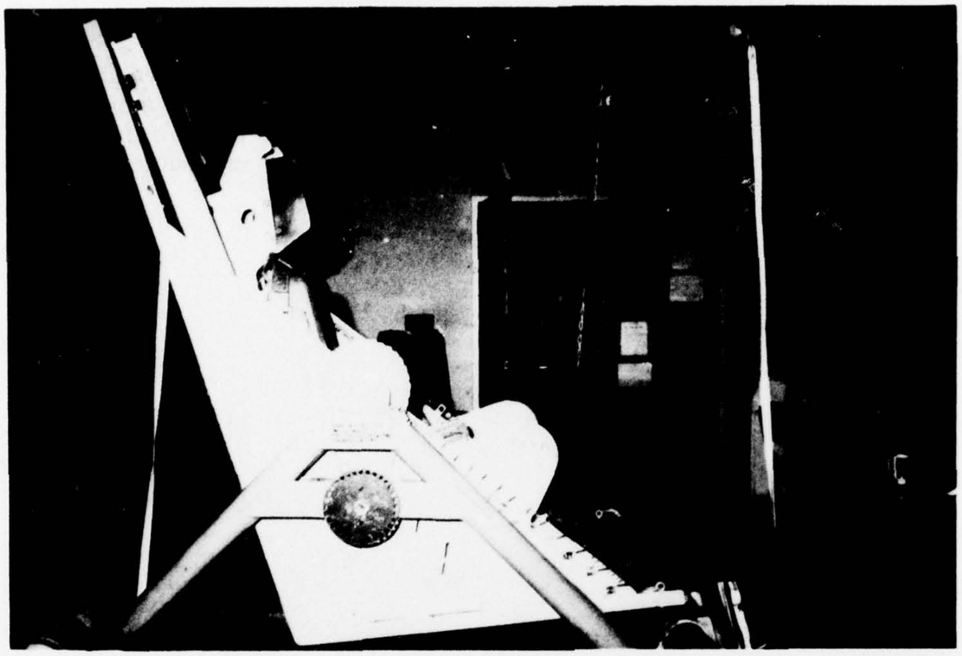


Figure 2
Test Platform Side View

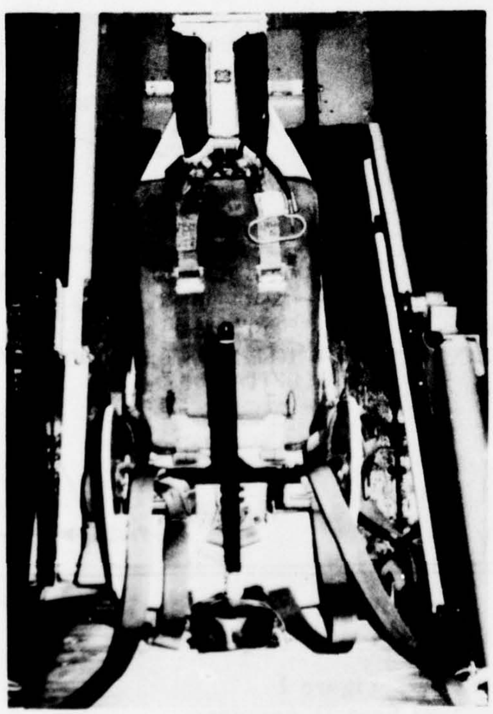


Figure 3
Test Platform Front View

2. The carriage of the mechanism is constructed of four 5 in. diameter (12.7 cm) steel pipes, welded to a chassis of four 6 in. (15.24 cm) steel pipes. The frame which carries the ejection seat and its occupant is constructed of plywood, reinforced on all sides with steel plates. An ESCAPAC IC-3 ejection seat, inert and with no modifications other than those allowing it to be mated to the test platform, is held in place between two steel rails inside the back of the frame and is rigidly secured by a single 1/2 in. (1.27 cm) steel rod passing through the rails (reinforced by a length of 2024 steel angle iron). The frame is supported on the carriage through a common-center axis at two hubs.

3. The frame was modified for the purposes of the laboratory study. Detachable straps were installed on the underside of the frame floor and on the reverse of the frame back, allowing inversion to be accomplished by selective manipulation of two hoists, positioned on either side of the carriage. This arrangement allowed precise control of the rates of onset of the G vectors used, insuring consistency from test to test. Other straps provided for positive braking of the mechanism after inversion or along any point during inversion. Control of the frame position was accomplished by reference to graduated markings on the frame's left axle hub so that any G loading could be duplicated during the tests. On the floor of the frame, a plywood extension was added to provide additional leg room and to supply a reference plane for the feet. Immediately in front of the seat, a mock control stick was installed, scaled, and positioned to conform to that found in F-8 type aircraft. The stick could move only fore-and-aft and was used as an indicator of the subjects' functional reach performance.

4. Spatial position recording equipment was installed on the frame of the mechanism (figure 4). On the right-hand side of the ejection seat, next to the inside right wall of the frame, a calibrated pivoting arm was attached. On the arm, a sliding sight was mounted, the combination permitting direct line-of-sight measurment of any point in the test platform, corrected for parallax. The measurements from this sight were in polar coordinates (with a constant offset), thus creating a "blind" to the experimenter and eliminating a source of bias (as the numbers obtained from the mechanism were not immediately decipherable). Wobble error of the arm was negligible. Lateral motion of the subjects, which could induce slight measurement errors, was controlled by proper positioning of the subjects (paragraph 7, appendix H).

5. Measurement of off-seat travel was accomplished by using a nylon line attached to the subject, routed down through the seat pan, and exiting the seat pan at the front, where the lower ejection handle usually rests (figure 5). Measurement of the distance traveled by the motion line yielded a corresponding distance which the body traveled upward (away from the seat pan). Stretch of the cable was not a factor due to the small loads placed upon it. Attachment of the cable to the subjects was accomplished by connecting its free end to an adhesive connector pad (situated over spinal process L-1) which was secured to the subject with Benzoin preparation, adhesive discs, and nylon tape (figure 6).

Figure 4
Pivoting Arm and Sliding Sight

Figure 5
Nylon Motion Line

Figure 6
Cable Attachment Disc

6. The ESCAPAC IC-3 ejection seat was used with an empty RSSK-8A seat pan survival kit. This provided a seat pan fit which, when properly anchored, eliminated all seat pan motion within the ejection seat, another source of total body motion. In addition, several experimental restraint straps were attached to the ejection seat. These experimental restraining devices should not be considered developmental prototypes destined for flight use - they were special restraints designed to accomplish restraint actions for the sole purposes defined in the study. The exact nature and function of these restraint devices is explained in the test protocol (appendix H).

## DESCRIPTION OF TEST PROTOCOL

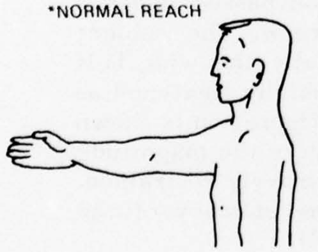
**1. Five human volunteer subjects, ranging from 10th to 90th percentiles in weight and from 25th to 94th percentiles in seated height, were used in this study (table I).**

### Table I

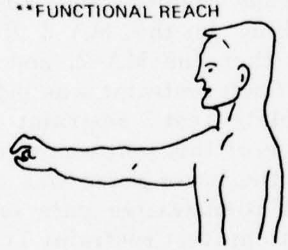
### Test Subject Anthropometry

| Subject I.D. | Weight | Stand Height | Seated Height | Seated Shoulder Height | * Normal Reach | ** Functional Reach | Normal Shoulder Breadth | Hip Breadth | Upper Thigh Circle | Lower Thigh Circle |
|---|---|---|---|---|---|---|---|---|---|---|
| B | 192 | 69.9 | 37.2 | 25.6 | 33.1 | 32.2 | 18.3 | 14.0 | 24.7 | 17.7 |
| (percentile) | 87% | 50% | 78% | 95% | 18% | 70% | 30% | 63% | 91% | 93% |
| P | 163 | 67.7 | 36.7 | 24.0 | 33.2 | 31.1 | 17.0 | 14.3 | 23.2 | 17.0 |
| (percentile) | 35% | 19% | 64% | 57% | 20% | 43% | 3% | 77% | 64% | 82% |
| F | 152 | 72.5 | 37.2 | 25.0 | 35.4 | 33.2 | 18.2 | 12.8 | 21.0 | 15.8 |
| (percentile) | 16% | 86% | 77% | 87% | 69% | 88% | 26% | 9% | 15% | 45% |
| L | 196 | 73.8 | 38.2 | 26.9 | 36.2 | 33.9 | 19.8 | 14.4 | 23.7 | 16.0 |
| (percentile) | 91% | 94% | 94% | 99% | 84% | 95% | 88% | 81% | 76% | 54% |
| R | 146 | 67.7 | 35.4 | 24.2 | 34.8 | 32.8 | 17.7 | 12.3 | 20.5 | 15.3 |
| (percentile) | 10% | 19% | 25% | 65% | 55% | 81% | 14% | 2% | 8% | 30% |

*NORMAL REACH



**FUNCTIONAL REACH



Normal Reach percentile values determined from Anthropometry of Flying Personnel, H. T. Hertzberg, G. S. Daniels, et. al., 1954

All other values determined from Anthropometry of Naval Aviators, E. C. Gifford, et. al., 1965

2. Six experimental restraint configurations were utilized:

a. Test Restraint 1: Test restraint Type 1 (figure 1) was the basic MA-2 Integrated Torso Harness, unmodified except for a cut-out portion in the rear to allow access to the subject's skin to permit mounting of the motion line connector. This test provided baseline data concerning body motion which occurs while using the MA-2, properly fitted and properly adjusted.

b. Test Restraint 2: Test restraint Type 2 utilized only that portion of the MA-2 which provided restraint to the seat pan (figure 2). Due to a lack of official nomenclature, this portion will be called the Bypass Web. Since the size of the Bypass Web varies with the size of the MA-2, each subject utilized a web of equal size to the one in his harness. This test provided data which, when compared to Test 1, would identify any tendency of the MA-2 to improve or hinder overall restraint.

c. Test Restraint 3: Test restraint Type 3 utilized the MA-2, a wide aircrew seat belt applied directly to the upper surface of the MA-2 lap belt (figure 3) and a set of Hip Immobilizing Belts (figure 4). Each end of the seat belt was attached to the frame of the ejection seat bucket, allowing its use as a safety belt on other test runs. The hip belt immobilized the hip at the acetabulum, minimizing compression of the joint and subsequent upward torso motion due to this compression factor. These hip belt straps were attached to the back of the RSSK-8A, crossed, and routed around the iliac crest of the subject to a dual connector on the front side of the seat pan. Connection of the hip straps required that they be passed under a piece of the supportive webbing in the MA-2 (figure 5). The subject connected the hip straps first, then the MA-2, and finally the wide belt (directly on top of the MA-2). Each restraint was individually tightened as they were connected. The complete Test 3 restraint configuration is shown in figure 6. The primary purpose of this test was to observe the magnitude of upper torso movement when the lower torso was effectively restrained. Secondarily, this test provided comparative data on the efficacy of the presently-installed restraint system (test restraint Type 1).

d. Test Restraint 4: Test restraint Type 4 was similar to Type 3, except that the Bypass Web was substituted for the MA-2. The purpose of this run was primarily to obtain data comparable to Test 3, while providing additional comparative information against all other tests.

e. Test Restraint 5: Test restraint Type 5 was identical to Type 3, with the addition of thigh restraints (figure 7) and foot traction restraints (figure 8). The thigh restraints were attached between the ejection seat and the rotating frame, immediately in front of the RSSK-8A. These allowed the subject to have his thighs restrained tightly against the seat pan, eliminating one source of leg motion. Upward motion of the legs below the knee could be adequately controlled by the subject; however, this required conscious effort. Preliminary studies showed a tendency for the legs to retract to the body when passing through +Gx. In order to counter this

effect, traction restraints were placed on each foot. The complete Type 5 restraint configuration is shown in figure 9. The primary purpose of this test configuration was to determine to what extent the lower extremities influenced body motion.

f. Test Restraint 6: Test restraint Type 6 was identical to Type 5 except that the Bypass Web was substituted for the MA-2. This test provided comparable data.

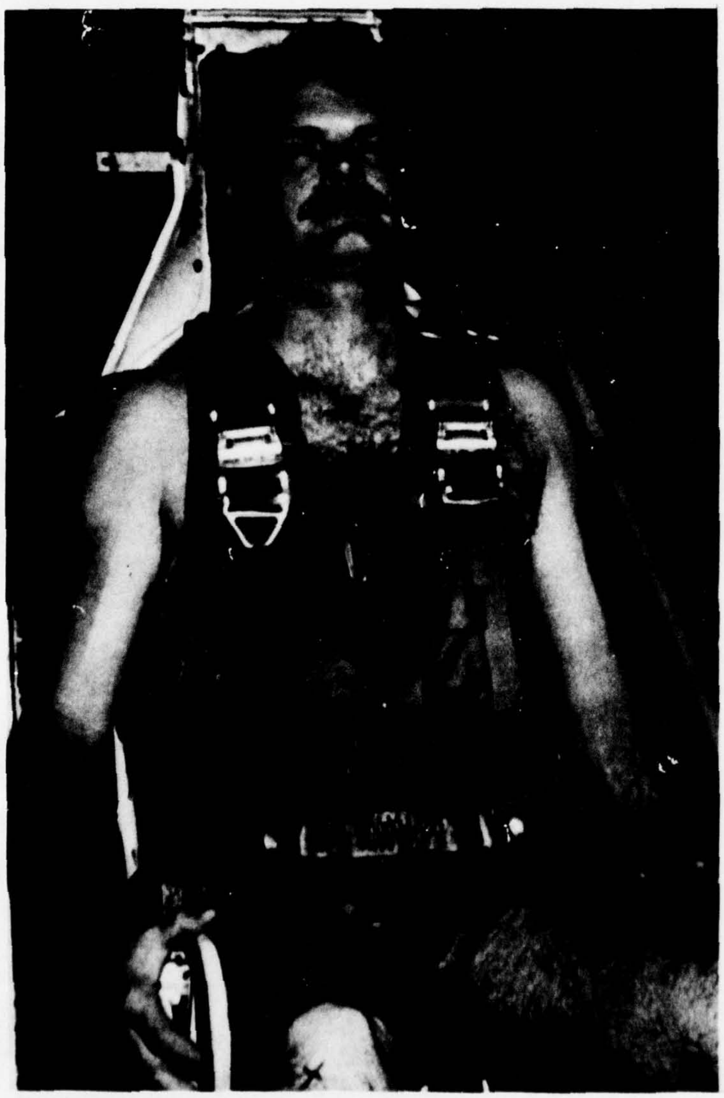


Figure 1
Test Restraint Configuration Type 1

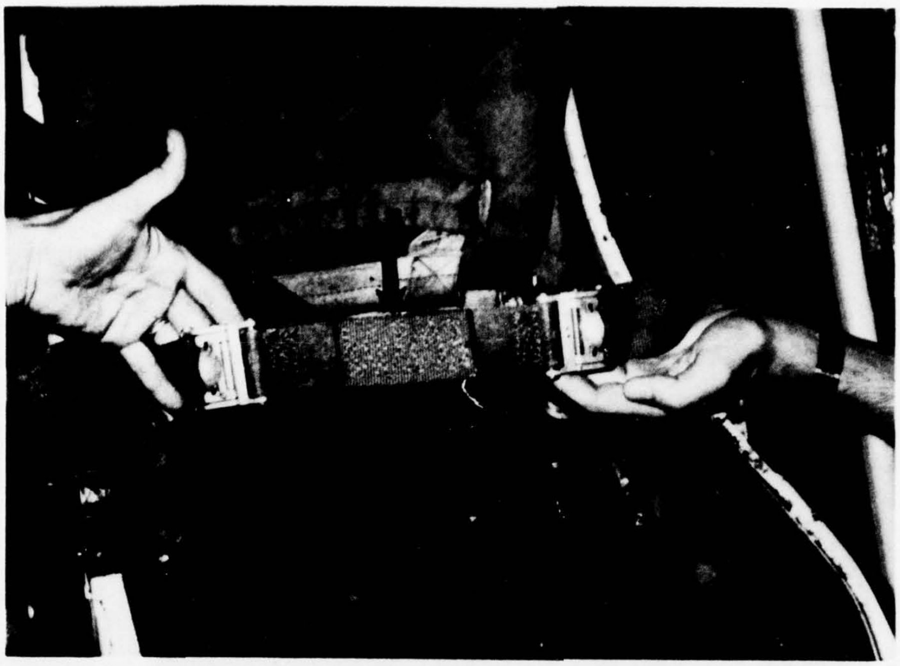


Figure 2
Test Restraint Type 2, Bypass Web

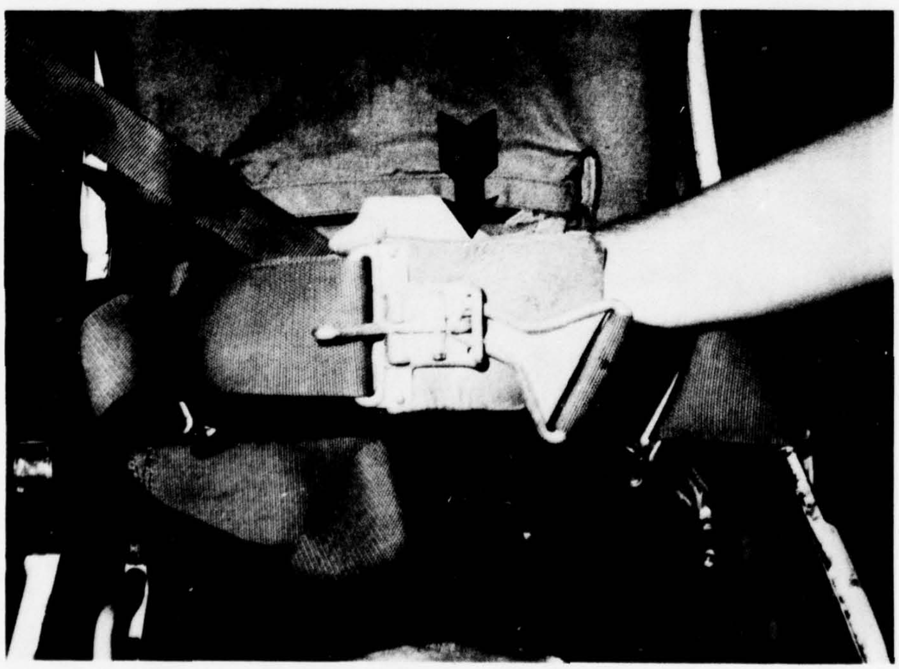


Figure 3
Wide Aircrew Retention Belt, Test Type 3

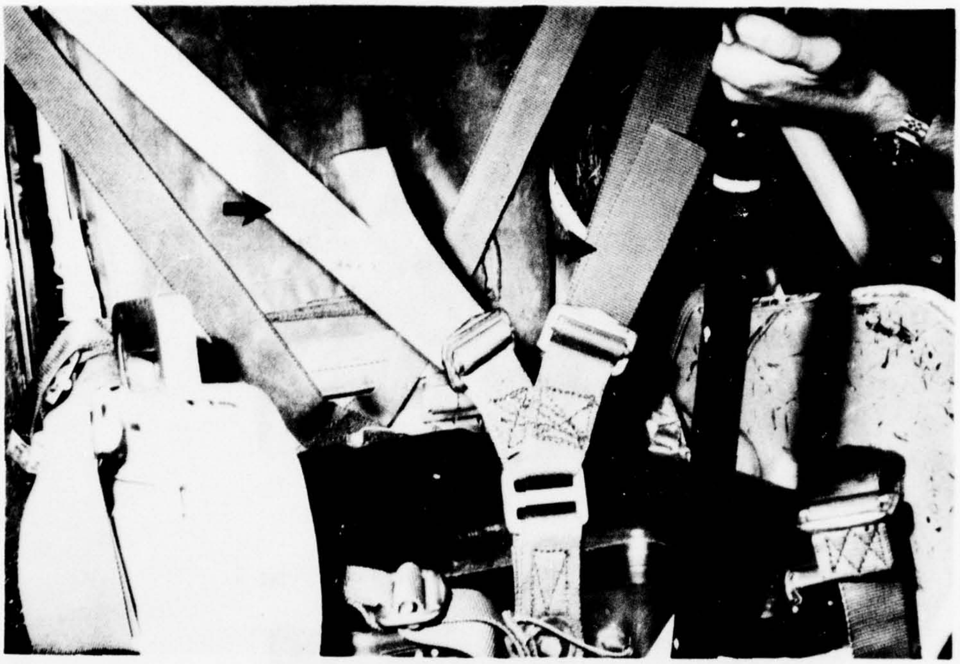


Figure 4
Hip Immobilizing Straps, Test Type 3

Figure 5
Routing of the Hip Immobilizing Restraint through the MA-2P

Figure 6
Subject Attaching Final Restraint for Test Type 3

Figure 7
Thigh Restraints, Test Type 5

Figure 8
Foot Traction Restraints, Test Type 5

Figure 9
Test Configuration, Test Type 5

3. Each of the five subjects performed each of the six tests five times in a backward rotational mode (+Gz through +Gx to -Gz). Two subjects performed tests using restraint Types 1 and 3 only in a forward rotational mode (+Gz through -Gx to -Gz). Military transfer accounted for subject attrition and nonavailability for the forward rotation tests. The forward rotation tests provided information on the effectiveness of the shoulder straps to restrain the upper torso during -1Gx.

4. Each subject was individually fited with an MA-2 Integrated Torso Harness in accordance with the procedures presented in the Aviation Crew Systems Manual, NAVAIR 13-1-6.2, to ensure a snug fit. Each subject wore only athletic shorts for the tests to eliminate the variability of textile bulk under the test restraints.

5. Prior to each test run, the subject donned his particular MA-2 and was briefed regarding the test protocol to be used. Key target points were then marked on the body in grease pencil. These target points consisted of: (1) the skin surface covering the mastoid process of the temporal bone superior to and behind the right earlobe (figure 10); (2) the surface covering the right acromial process at the shoulder joint (figure 10); (3) the skin surface covering the most distal point of the right knee (referenced to the seated position, figure 11); and (4) the skin covering the junction of the right navicular and cuboid bones (figure 11). In addition, an adhesive disc for attachment of the nylon motion line was affixed to the skin above the spinal column in the area of L-1 (figure 12). Connection to the motion line took place after the subject was seated.

Figure 10
Target Points for Measuring Head and Shoulder Movement

Figure 11
Target Points for Measuring Knee and Foot Movement

Figure 12
Adhesive Disc Attachment

6. Following the above preparation, the subject was seated in the ejection seat, attached to the appropriate restraints, and given a preflight briefing to insure proper subject positioning and actions during the run. To insure consistency in restraint attachment, each subject was strapped in by an assistant, and the adjusting points marked on the straps were checked after each run to detect any slippage of the lap belts.

7. Prior to inversion, baseline data concerning the relative position of the head, shoulder, knee, and foot were obtained. In addition, the nylon motion line was marked and forward stick motion measured. Subject positioning for these measurements was of paramount importance. To insure repeatability of body positions and measurements, the subjects were instructed to assume specific postures. For measurement of the head position, the subject was instructed to keep his head against the headrest, chin tucked in firmly. For measurement of the shoulder position, the subject's right hand was placed on a particular portion of the ejection seat while measurements were made (figure 13). Measurement of subject reach required the subjects to assume the posture shown in figure 14. Grasping of the stick was controlled by allowing only the two-finger grip shown in figure 15, with the web of the thumb aligned with a marker line on the stick. It should be noted that this measurement does NOT reflect functional reach, nor should it be confused with the actual aircraft control stick throw, but rather is an indication of effective reach degradation during adverse G loads. Subject positioning for stick position measurement required pushing the stick as far forward as possible, once while maintaining the back against the parachute pack and once while leaning fully against the locked inertia reel. Positioning of the feet was accomplished (tests 1, 2, 3, and 4) by forcing the heels of both feet forward and against the floorboard, while flexing the toes backward as much as possible. This was not required in tests 5 and 6 due to the use of leg restraints.

Figure 13
Position of Hand for Shoulder Measurement

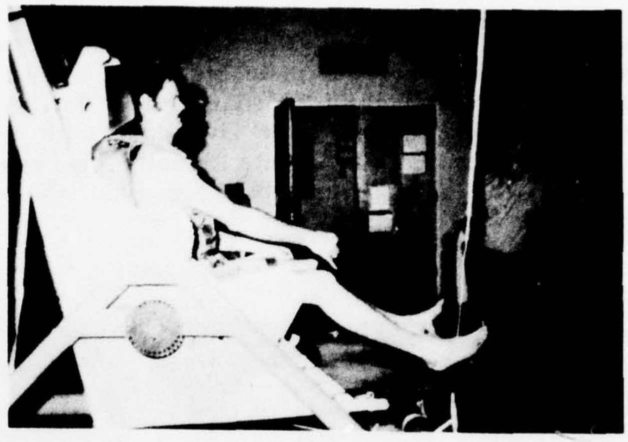


Figure 14
Posture for Forward Stick Throw

Figure 15
Stick Grasp

8. Inversion of test subjects (figure 16) was accomplished by coordinating the movement of two overhead pulley devices. During the inversions, the subjects were instructed to keep their hands in their laps and not to exert any force against the floorboard with their feet in order to minimize subject-induced travel off the seat. Inversion was held in the -Gz attitude just long enough to obtain the measurements described in paragraph 7, and then the subject was immediately returned to the upright position for 10 min "in seat" rest prior to commencing the next test run. The subjects remained in the seat without doffing or relaxing any restraints during the entire test period (five inversions with four rest periods). Immediately following each run, assistants visually checked all restraints for evidence of slippage. The rest periods between runs allowed the body to regain its +Gz compression.

Figure 16
Test Subject in -1 Gz Attitude

AIRCREW PERSONNEL RESTRAINT QUESTIONNAIRE

Name (Optional) ______________________________ Squadron ______________

Age __________ Weight _________ Height ____________

Sitting Height (if known) __________

Crew Station: Pilot ______ B/N ______ RIO/MCO ______ Other (specify) _____

1. Please list all tactical jet aircraft with ejection seats in which you have had flight experience.

2. Please indicate the different articles of clothing you have worn under your MA-2 integrated torso suit.

959 Flight suit.

333 CWU-33/P antiexposure suit.

258 Mark 5A antiexposure suit.

97 Other exposure suit; specify.

749 Cold weather underwear.

473 Ventilated wet suit.

370 Winter flying suit, jacket.

113 Winter flying suit, trousers.

681 MK-2A anti-G coverall.

3. Which of the following size (s) MA-2 integrated torso harness do you usually wear?

| | | |
|---|---|---|
| 20 Small Short | 66 Medium Short | 33 Large Short |
| 46 Small Regular | 249 Medium Regular | 138 Large Regular |
| 22 Small Long | 211 Medium Long | 217 Large Long |
| 3 X-Large Short | 25 X-Large Regular | 64 X-Large Long |
| 9 XX-Large Long | | |

4. If you wear more than one size harness, why?

5. Were you specially fitted for your MA-2 Integrated Torso Harness?

663 Yes 316 No 3 Blank

6. If yes, was it by

646 Your parachute rigger 13 Other; specify. 323 BLANK

7. Do you fly with your MA-2 integrated torso suit?

425 Tight (=1) 539 Snug (=2) 12 Loose (=3) 6 BLANK

8. Do you consider it to be

84 Uncomfortable (=1) 547 Slightly uncomfortable (=2)

339 Comfortable (=3) 12 BLANK

9. Which do you consider more important?

194 Comfort (=1) 692 Optimal restraint under all flight regimes (=2)

81 BOTH (=3) 15 BLANK

10. Do you usually have difficulty donning or doffing your MA-2 integrated torso suit?

Donning (=A): 122 Yes 854 No 6 BLANK

Doffing (=B): 46 Yes 909 No 27 BLANK

11. Do you normally experience any problems tightening the lap belt straps while in the seat?

377 Yes 600 No 5 BLANK

12. If yes, in which aircraft?

13. Do you consider any lap belt/adjuster configuration to be better than others?

225 Yes 628 No 129 BLANK

14. If yes, which aircraft has the better configuration; why?

15. Do you normally loosen your lap belt due to discomfort?

103 Yes 863 No 16 BLANK

16. After what length of time does discomfort necessitate readjustment of the lap belt straps?

35 Less than 1 hr (=1) 72 1/2 to 1 hr (=2)

138 1 to 2 hr (=3) 326 More than 2 hr (=4) 411 BLANK

17. Approximately what percentage of the time do you fly with the inertia reel locked?

737 Only takeoffs and landings (=1)

94 10% (=2) 42 50% (=4)

37 25% (=3) 24 75% (=5) 48 BLANK

18. Do you usually use the shoulder strap adjusters on the MA-2 integrated torso harness?

91 Yes 878 No 13 BLANK

19. Is the amount of adjustment provided sufficient?

421 Yes 93 No 468 BLANK

20. Approximately what percentage of ACM, DCM, or weapons delivery do you experience zero or negative G's.

687 0 - 10 (=1) 12 51 - 75 (=4)

215 11 - 30 (=2) 24 76 - 100 (=5) 22 BLANK

22 31 - 50 (=3)

21. Have you experienced head-to-canopy contact during flight?

694 Yes 286 No 2 BLANK

22. If yes, in which aircraft?

23. If yes, what were the flight conditions?

24. Does your restraint system provide adequate lateral (side to side) restraint during rapid or violent maneuvering?

707 Yes 246 No 29 BLANK

25. Have you ever experienced any temporary loss of aircraft control during situations such as negative G, ACM, DCM, buffeting, or turbulence?

415 Yes 495 No 72 BLANK

26. If yes, was the loss of control because of an inadequacy in the MA-2 integrated restraint system?

75 Yes 334 No 573 BLANK

27. If yes, explain the maneuver and control loss.

28. If you have lost control, did the MA-2 integrated restraint system hinder your attempt to regain control?

65 Yes 475 No 442 BLANK

29. If yes, in what way was the restraint inadequate and how did this inadequacy hinder your attempt to regain control?

30. Do you consider the MA-2 integrated restraint configuration an adequate restraint system?

772 Yes 174 No 36 BLANK

31. Do you feel there are any deficiencies with the MA-2 integrated restraint system?

533 Yes 398 No 51 BLANK

If yes, explain the deficiencies.

32. Do you feel that powered lap belt tightening in addition to a ballistic inertia reel for pre-ejection positioning would be desirable?

551 Yes 342 No 89 BLANK

## SPECIFIC QUESTIONS REQUIRING QUANTITATIVE EVALUATION OF RESPONSES

1. Is there any evidence in the questionnaire results that the MA-2 Integrated Torso Harness provides inadequate restraint?

   a. Was there any evidence of difficulty adjusting the MA-2 to the user?

   b. Was the MA-2 specifically addressed as the cause for loss of aircraft control? Were the causes specifically defined?

   c. Was the MA-2 specifically addressed as the cause for difficulty in recovering aircraft control? Were the causes specifically defined?

   d. Did the sample population express a desire for an improved restraint system?

   e. Was the MA-2 reported as being an inadequate restraint component?

   f. Were any deficiencies found to exist in the MA-2?

   g. Were any deficiencies specifically defined in the MA-2?

   h. Were there specific variations in response between the following sets of sample populations?

      (1) Entire population versus population that did not lose control of their aircraft (25 = NO)?

      (2) Entire population versus population that did lose control also blamed the MA-2 for such loss and blamed the MA-2 for interfering with recovery (25, 26, and 28 = YES)?

      (3) Entire population versus population that did lose control but did not blame the MA-2 (25 = YES, 26 and 28 = NO)?

      (4) Population that lost control and blamed the MA-2 (25, 26, and 28 = YES) versus population that lost control and did not blame the MA-2 (25 = YES, 26 and 28 = NO)?

      (5) Population that lost control of the aircraft versus population that did not lose control of the aircraft?

      (6) Population specially fitted for their MA-2 versus population that received no special fitting attention?

      (7) Population that experienced head-to-canopy contact versus the population that did not experience head-to-canopy contact?

      (8) Any other population sample not mentioned here which appears to significantly affect results?

2. Is there any evidence in the questionnaire results that the restraint subsystems (lap belt, inertia reel, or associated straps and connectors) have contributed to inadequate restraint?

a. Did the sample population experience difficulty tightening their lap belts?

b. Did the sample population identify specific aircraft in which the subsystem difficulties have been encountered?

c. Did the sample population initiate readjustment of the lower restraint subsystems while in flight? If so, during what time frames?

d. Did the sample population initiate readjustment of the upper restraint subsystems (inertia reel lock) while in flight? If so, during what time frame?

e. Are there significant variations between the specific groups identified in question 1.h?

3. How did the sample population express their attitudes toward restraint?

a. How did they rate the MA-2 in terms of comfort?

b. How did they rate their own habits in terms of adjusting the MA-2 (tight, snug, loose)? How does this reflect their orientation or attitudes toward restraint?

c. How did the sample population tend to wear their lap belts? How does this compare to the attitudes reflected in question 3.b?

d. Was there any evidence of restraint readjustment in flight for comfort?

e. Was there any evidence of restraint readjustment in flight for increased restraint value?

f. Were there any significant variations between the specific groups identified in question 1.h?

4. Does the questionnaire give any evidence which would indicate a lack of satisfaction, or a failure to accept, the present restraint subsystems and the MA-2 Integrated Torso Harness?

a. Were other systems and subsystems identified as being superior to the MA-2 or the presently used lap belt configuration? Which ones?

b. Was a desire expressed for improved systems or subsystems?

c. Was the MA-2 rated as being an inadequate restraint system by any cross-section of the sample population?

d. Were there any significant variations between the specific groups identified in question 1.h?

## EXCERPTS FROM MEDICAL OFFICER REPORTS IN WHICH INADEQUATE RESTRAINT APPEARED TO HAVE COMPROMISED EJECTION

**NOTE: Due to restrictions on distribution of identified accident data, none of the excerpts are identified as to their specific accident.**

1. "During a test flight, this A-4 aircraft entered uncontrollable roll and rapidly lost altitude. The pilot, unable to reach face curtain due to negative G's, initiated ejection by secondary handle."

2. "During ACM in an A-4 aircraft, pilot encountered violent negative G's progressing into an inverted spin. Pilot was thrown forward into glareshield and was pinned against the canopy. Pilot experienced some difficulty reaching lower firing handle due to negative G's pinning him against the canopy."

3. "The B/N in a KA-6D aircraft was forced up in the cockpit due to negative G's following a mid-air collision. Unable to reach lower ejection handle, he pulled face curtain around shoulders."

4. "This A-4 aircraft was in chase position in a tactical maneuver when it departed controlled flight. Due to negative G's, pilot was pushed up against the canopy and was unable to reach face curtain. He used lower ejection handle to initiate ejection."

5. "This A-4 aircraft was 80 deg nose down in a descending spiral. The pilot was up in his seat and loose in torso harness due to negative G's and had to flex his neck in order to pull face curtain."

6. "Following a mid-air collision, both pilot and copilot of this A-4 aircraft experienced difficulty locating and pulling face curtain."

7. "This A-4 aircraft departed controlled flight and entered spin. Due to negative G's, pilot was pinned against canopy. Pilot had to move head forward to reach face curtain."

8. "Due to erratic and tumbling condition of this A-7 aircraft due to a mid-air collision, pilot was unable to reach face curtain so he used seat pan handle."

9. "Following impact of a mid-air collision, this A-7 aircraft went out of control, 90 deg nose down. Due to negative G's, the pilot was forced up in the cockpit. He pushed himself back into the seat by using the canopy and then ejected using the alternate handle."

10. "During DCM training flight in an A-7, pilot induced stall and aircraft departed controlled flight. Due to negative G's, pilot was hanging in straps with head in plexiglass in top of canopy. Pilot managed to pull himself down into seat and eject via lower ejection handle."

11. "Following mid-air collision, pilot of this A-7 aircraft was thrown up against canopy and was unable to see. He grasped the lower ejection handle with three fingers and ejected as he pulled himself down toward the seat."

12. "Following a mid-air collision, this F-8 aircraft began violent maneuvers. The G forces caused pilot to be hunched forward into straps. Pilot had unlocked inertia reel during climb out. Pilot could not see out because he could not raise his head. He was unable to reach face curtain so he ejected with lower ejection handle while bent forward in straps."

13. "During ACM training flight, this F-9 aircraft stalled and entered inverted spin. Pilot had to put himself down in the seat in order to reach face curtain."

14. "During training flight, this F-4 aircraft experienced a control malfunction. The student ejected with the alternate handle since negative G's prevented him from reaching the face curtain."

# EXCERPTS FROM MEDICAL OFFICER REPORTS IN WHICH INADEQUATE RESTRAINT APPEARED TO HAVE CONTRIBUTED TO THE LOSS OF THE AIRCRAFT

**NOTE: Due to restrictions on distribution of identified accident data, none of the excerpts are identified as to their specific accident.**

1. "Student pilot in T-2 induced aircraft departure while performing Cuban Eight. Student was 'hanging in his straps' because he had not properly tightened his lap belt and was not able to apply proper control inputs to right the aircraft. Loose lap belt prevented pilot from effectively controlling aircraft while it was inverted."

2. "Student pilot inadvertently departed aircraft (T-2) while in air-to-air gunnery pattern. The departure placed him in a negative G situation and since his lap belt was not tightened, he was thrown up against the canopy with the back of his helmet touching and forcing his tead to tilt forward. At departure, when thrown off the seat, pilot released controls and put his hands up to protect himself. Pilot could not neutralize controls because he was unable to reach the stick, rudders, or power levers due to hanging in the straps and dazed condition. At 8,000 feet, pilot pushed himself away from the canopy with his right hand and pulled alternate handle with his left hand."

3. "Pilot flying a T-2 aircraft pulled excessive angle of attack during ACM which resulted in departure from controlled flight. Pilot's seat belts were not properly secured, allowing him to float out of his seat and become pinned against the canopy during negative G flight. It's believed that had he been properly secured in his seat, he would have been able to reach controls and effect a safe recovery."

4. "Instructor and student were on an acrobatic training flight in a T-2. Instructor demonstrated a nose high inverted attitude and gave aircraft to student for recovery. As the aircraft was rolling wings level upright, the nose of the aircraft pitched down, resulting in negative G's. At this time, the student was pulled out of his seat by the negative G's and experienced difficulty controlling the nose attitude of the aircraft. After pulling himself back into the seat, student applied back pressure on the stick with no response. Instructor then applied back pressure but still the aircraft did not respond. Due to increasing airspeed, steep dive angle, and rate at which aircraft was closing with the ground, the instructor initiated ejection. The aircraft was established to have a full nose-down trim following the accident. It was suggested that the most probable cause of the full nose-down trim was the student clutching of the control stick and his inadvertent pressure on the trim button while trying to replace himself in the seat."

5. "Pilot in A-4 departed controlled flight during ACM and progressed into inverted spin with violent negative G's. Pilot was thrown forward into glare shield, shattering his visor and causing superficial lacerations above left eye. Faced with a quickly deteriorating situation, unable to reach controls or read his instruments, and violently forced against canopy under the negative G's, the pilot ejected."

6. "Pilot making scissor roll during ACM departed his A-4 aircraft and entered violent inverted spin. Pilot's helmet was cracked as head was thrown about in the cockpit. He sustained various bruises as body was forced against left side of canopy. Pilot's dazed/confused condition, resulting in loss of time at altitude, coupled with inability to readily read instruments and reach controls due to violent spin, virtually eliminated chances of recovery by 10,000 feet, so pilot ejected."

7. "During an annual NATOPS check flight, this A-7 aircraft departed controlled flight and entered inverted spin. Due to negative G's, pilot and copilot were forced up against canopy, making it difficult to read instruments and reach controls. AAR stated inadequate lap belt restraint system caused pilot to be unable to reach ejection mechanism, apply corrective action, or read his instruments."

8. "A-4 aircraft was in chase position in tactical maneuvers when it departed controlled flight and entered inverted spin. Pilot did not have straps tight enough to prevent his being pushed up and to the right against the canopy. This caused difficult reaching of the rudder pedals and hampered the use of other controls. This situation was a major factor in the pilot being unable to recover the aircraft."

9. "During routine flight in the F-4, the aircraft, without any prior warning, pitched violently upward. The high degree of positive vertical G forces caused the pilot to be bent over so that his head was approximately one inch above his knees. He became totally incapacitated; i.e., unable to use his controls to try to correct the situation nor could he reach either ejection seat deploying device. RIO had to initiate ejection."

10. "F-9 aircraft experienced apparent runaway nose-down trim during vertical recovery from air intercept run. Violent nose-down pitch occurred which put student pilot 'hanging in his straps.' Pilot, due to negative G's, was unable to shut off flying-tail, which might have corrected the problem."

11. "Prior to takeoff for ACM, pilot of this A-7 noted slight difficulty in tightening lap belt on the left side but felt it was satisfactory. During ACM, aircraft departed controlled flight and entered a spin. Because of loose lap belt, pilot was pushed up and away from seat. Unable to get proper control inputs because of being pinned against canopy and passing through 10,000 feet, pilot elected to eject. Pilot reached for the face curtain but was unable to because of loose straps. He twisted his body to the right and bent forward and grabbed lower ejection handle with right hand and pulled."

12. "Mecnanical failure occurred without prior warning, resulting in a loss of control of this A-7 aircraft. Pilot was pinned against canopy and unable to assess the cause of the failure. Unable to reach face curtain because of being pinned against canopy, pilot reached for lower ejection handle but could not find it. Pilot pushed himself back down into the seat by pulling on left strap with left hand. He then reached for face curtain with right hand and then rapidly brought left hand up to face curtain and pulled."

13. "During a test maneuver investigating high angle of attack characteristics, this F-14A aircraft departed controlled flight and progressed into a flat spin imposing -7 G's (eyeballs out) on pilot and -5 G's (eyeballs out) on NFO. Failure to utilize premaneuver checklist led to failure of both pilot and NFO to lock shoulder harness. Having entered maneuver without harness locked, the pilot and flight officer were immediately malpositioned in their cockpits as increasing G forces moved them forward in their harnesses. Movement forward was at too slow a rate, however, to activate the inertia reel lock feature of the shoulder harness system. The pilot, with his face on the instrument panel, could not reach controls. It is possible that the pilot may have been successful in recovering the aircraft had he

not been forced forward into the instrument panel. This situation not only compromised the pilot's ability to recover the aircraft, but also allowed significant malpositioning of both pilot and NFO in their seats prior to ejection."

14. "During ACM flight, this F-8 aircraft suddenly experienced a departure. The pilot's attempt to recover the aircraft was seriously degraded by negative G forces and buffeting pinning pilot to canopy and making controls inaccessible."

15. "During ACM flight, this F-8 aircraft suddenly experienced a departure. Lateral G forces pinned the pilot against the right side of the canopy and extreme buffeting caused his head to repeatedly bang the side of the canopy. Dazed and being unable to read instruments or reach controls, pilot ejected."

16. "During a shallow left climbing turn, this F-8 aircraft abruptly and without warning rolled violently left and entered unknown maneuver which pinned pilot's head against radar scope and forced feet forward and off rudder pedals. Attempts to regain control of aircraft resulted in other violent, uncontrolled maneuvers which might have been caused by erroneous control inputs."

# DATA MASTER FROM LABORATORY STUDY
# (RAW DATA)

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /39.2 | 91 /33.2 | 31 /27.8 | 10 /38.2 | 40 /32.4 | ////////// |
| * | +Gx | 92 /41.0 | 92 /35.6 | 32 /26.7 | 10 /36.7 | 42 /31.8 | ////////// |
| * | -Gz | 92 /42.9 | 91 /37.7 | 34 /27.1 | 11 /36.3 | 47 /30.0 | 2.25 |
| 2 | +Gz | 92 /39.1 | 91 /33.2 | 31 /27.8 | 10 /38.1 | 41 /32.5 | ////////// |
| * | +Gx | 92 /40.9 | 92 /36.0 | 33 /26.7 | 10 /37.0 | 42 /31.8 | ////////// |
| * | -Gz | 91 /42.8 | 91 /37.5 | 33 /26.7 | 10 /36.6 | 47 /29.7 | 2.375 |
| 3 | +Gz | 92 /38.9 | 90 /33.4 | 30 /28.0 | 10 /38.3 | 39 /32.6 | ////////// |
| * | +Gx | 92 /40.7 | 91 /35.6 | 33 /26.5 | 10 /37.0 | 41 /31.8 | ////////// |
| * | -Gz | 91 /42.7 | 91 /38.1 | 33 /26.9 | 10 /36.3 | 47 /30.0 | 2.875 |
| 4 | +Gz | 92 /39.0 | 90 /33.2 | 30 /28.4 | 10 /38.4 | 40 /32.6 | ////////// |
| * | +Gx | 92 /41.0 | 92 /36.5 | 32 /26.5 | 10 /37.3 | 43 /31.4 | ////////// |
| * | -Gz | 91 /43.2 | 91 /38.0 | 33 /26.7 | 10 /36.7 | 46 /30.2 | 2.00 |
| 5 | +Gz | 92 /39.0 | 91 /33.5 | 31 /28.1 | 10 /38.0 | 40 /32.6 | ////////// |
| * | +Gx | 92 /40.8 | 91 /36.2 | 32 /26.5 | 10 /37.1 | 43 /31.4 | ////////// |
| * | -Gz | 92 /43.0 | 90 /38.4 | 33 /26.8 | 10 /36.4 | 48 /29.5 | 2.875 |

Negative "G" Restraint Data Master
Raw Data

Subject I.D. - B    Restraint Type - I

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 91 /38.8 | 90 /33.2 | 30 /28.2 | 10 /39.3 | 38 /33.5 | /////////// |
| * | +Gx | 92 /40.9 | 93 /36.8 | 32 /26.6 | 10 /37.8 | 40 /32.2 | /////////// |
| * | -Gz | 92 /42.1 | 93 /37.8 | 33 /27.0 | 10 /37.0 | 44 /30.8 | 1.625 |
| 2 | +Gz | 92 /39.4 | 91 /34.0 | 31 /27.6 | 10 /38.5 | 40 /33.0 | /////////// |
| * | +Gx | 91 /41.0 | 93 /37.1 | 31 /26.4 | 10 /37.4 | 41 /32.0 | /////////// |
| * | -Gz | 92 /42.4 | 91 /37.6 | 33 /26.8 | 10 /36.7 | 46 /30.3 | 1.375 |
| 3 | +Gz | 92 /39.4 | 90 /33.7 | 32 /27.5 | 10 /37.7 | 40 /33.1 | /////////// |
| * | +Gx | 92 /40.9 | 93 /36.7 | 32 /26.6 | 10 /37.2 | 43 /31.5 | /////////// |
| * | -Gz | 92 /42.3 | 92 /38.4 | 35 /26.9 | 10 /36.5 | 46 /30.4 | 1.625 |
| 4 | +Gz | 92 /39.1 | 90 / 33.4 | 30 /28.4 | 10 /38.9 | 40 /32.8 | /////////// |
| * | +Gx | 92 /40.9 | 93 / 36.7 | 32 /26.7 | 10 /37.5 | 44 /31.4 | /////////// |
| * | -Gz | 92 /42.2 | 93 /37.8 | 33 /27.2 | 10 /36.9 | 46 /30.2 | 1.825 |
| 5 | +Gz | 92 /39.3 | 90 /33.5 | 31 /27.8 | 10 /38.7 | 40 /33.1 | /////////// |
| * | +Gx | 92 /40.7 | 92 /36.2 | 32 /26.8 | 10 /37.8 | 44 /31.0 | /////////// |
| * | -Gz | 92 /42.6 | 92 /38.6 | 35 /26.9 | 10 /36.7 | 47 /30.3 | 2.00 |

Negative "G" Restraint Data Master
Raw Data

Subject I.D. - B     Restraint Type - II

Negative "G" Restraint Data Master
Raw Data

Subject I.D. - F          Restraint Type - III

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /38.5 | 90 /33.6 | 30 /27.7 | 10 /38.5 | 40 /33.3 | ////////// |
| * | +Gx | 93 /40.0 | 92 /36.7 | 31 /26.8 | 10 /38.6 | 41 /32.2 | ////////// |
| * | -Gz | 92 /41.2 | 91 /37.2 | 32 /27.4 | 10 /38.0 | 42 /32.0 | 1.125 |
| 2 | +Gz | 92 /38.4 | 90 /33.3 | 30 /28.0 | 09 /39.2 | 38 /33.5 | ////////// |
| * | +Gx | 93 /40.0 | 93 /36.5 | 31 /27.1 | 10 /38.5 | 41 /32.3 | ////////// |
| * | -Gz | 92 /41.3 | 92 /36.9 | 31 /27.5 | 10 /38.8 | 44 /31.2 | 0.75 |
| 3 | +Gz | 92 /38.7 | 90 /33.2 | 30 /27.8 | 10 /39.2 | 40 /33.0 | ////////// |
| * | +Gx | 93 /40.0 | 93 /36.5 | 30 /27.1 | 10 /38.6 | 42 /31.9 | ////////// |
| * | -Gz | 92 /41.0 | 91 /37.3 | 31 /27.6 | 10 /38.7 | 43 /31.4 | 0.625 |
| 4 | +Gz | 92 /38.5 | 90 /33.2 | 30 /28.0 | 10 /39.3 | 40 /33.1 | ////////// |
| * | +Gx | 93 /39.8 | 93 /36.6 | 30 /27.1 | 10 /38.6 | 43 /31.5 | ////////// |
| * | -Gz | 92 /41.2 | 91 /37.4 | 31 /27.6 | 10 /38.7 | 44 /31.1 | 1.00 |
| 5 | +Gz | 92 /38.6 | 90 /33.1 | 30 /27.9 | 10 /39.1 | 40 /33.1 | ////////// |
| * | +Gx | 93 /39.8 | 93 /36.0 | 31 /27.1 | 10 /38.5 | 42 /32.1 | ////////// |
| * | -Gz | 92 /41.2 | 91 /37.8 | 31 /27.7 | 10 /38.8 | 44 /31.2 | 1.125 |

Negative "G" Restraint Data Master
Raw Data
Subject I.D. - B Restraint Type - IV

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /38.7 | 90 /33.1 | 31 /28.4 | 10 /39.1 | 40 /33.0 | ////////// |
| * | +Gx | 93 /39.7 | 92 /35.6 | 32 /27.3 | 10 /38.3 | 40 /32.7 | ////////// |
| * | -Gz | 93 /40.5 | 93 /37.5 | 33 /28.3 | 10 /37.4 | 44 /31.5 | 0.625 |
| 2 | +Gz | 92 /38.4 | 91 /33.6 | 30 /28.2 | 10 /38.8 | 38 /33.5 | ////////// |
| * | +Gx | 92 /39.9 | 93 /36.1 | 32 /27.0 | 10 /37.9 | 40 /32.7 | ////////// |
| * | -Gz | 92 /41.0 | 93 /37.5 | 33 /27.8 | 10 /37.2 | 45 /30.8 | 0.625 |
| 3 | +Gz | 92 /38.8 | 90.5/33.1 | 31 /27.6 | 10 /38.6 | 40 /33.1 | ////////// |
| * | +Gx | 92 /40.2 | 93 /36.8 | 33 /26.7 | 10 /37.3 | 40 /32.8 | ////////// |
| * | -Gz | 92 /41.1 | 93 /37.7 | 34 /27.6 | 10 /37.2 | 43 /31.7 | 0.625 |
| 4 | +Gz | 92 /38.7 | 94 /32.6 | 31 /28.2 | 10 /38.6 | 39 /33.5 | ////////// |
| * | +Gx | 92 /40.2 | 93 /36.1 | 33 /26.9 | 10 /37.4 | 41 /32.4 | ////////// |
| * | -Gz | 92 /41.2 | 92 /37.5 | 34 /27.8 | 10 /37.2 | 42 /31.9 | 0.625 |
| 5 | +Gz | 92 /38.8 | 91 /33.0 | 31 /28.0 | 10 /38.6 | 41 /32.5 | ////////// |
| * | +Gx | 92 /40.3 | 93 /36.4 | 33 /26.7 | 10 /37.4 | 42 /32.8 | ////////// |
| * | -Gz | 92 /41.2 | 93 /37.7 | 34 /27.6 | 10 /37.4 | 41 /31.3 | 0.625 |

Negative "G" Restraint Data Master
Raw Data

Subject I.D. - B Restraint Type - V

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /38.4 | 91 /32.7 | 29 /28.2 | 08 /40.5 | 41 /32.8 | ////////// |
| * | +Gx | 93 /39.4 | 93 /35.2 | 30 /27.6 | 09 /39.9 | 43 /31.6 | ////////// |
| * | -Gz | 93 /40.6 | 92 /37.4 | 31 /28.3 | 09 /40.1 | 44 /31.3 | 1.125 |
| 2 | +Gz | 92 /38.5 | 91 /32.8 | 28 /28.3 | 07 /40.3 | 41 /32.3 | ////////// |
| * | +Gx | 93 /39.7 | 93 /35.4 | 30 /27.5 | 08 /39.6 | 42 /31.7 | ////////// |
| * | -Gz | 92 /41.0 | 91 /37.9 | 31 /28.1 | 09 /40.0 | 45 /31.2 | 1.125 |
| 3 | +Gz | 92 /38.5 | 90.5/32.8 | 28 /28.1 | 07 /40.3 | 40 /32.8 | ////////// |
| * | +Gx | 93 /39.8 | 93 /35.4 | 30 /27.4 | 08 /39.6 | 42 /31.6 | ////////// |
| * | -Gz | 92 /41.1 | 91 /38.0 | 31 /28.0 | 09 /39.9 | 44 /31.3 | 1.625 |
| 4 | +Gz | 92 /38.4 | 90.5/30.3 | 28 /28.2 | 07 /40.3 | 40 /32.9 | ////////// |
| * | +Gx | 93 /39.7 | 93 /35.8 | 30 /27.5 | 08 /39.8 | 41 /32.1 | ////////// |
| * | -Gz | 92 /41.3 | 91 /37.8 | 31 /28.0 | 09 /40.0 | 44 /31.3 | 1.625 |
| 5 | +Gz | 92 /38.8 | 90 /32.8 | 29 /28.2 | 07 /40.2 | 40 /33.0 | ////////// |
| * | +Gx | 93 /40.0 | 93 /35.7 | 30 /27.3 | 08 /39.4 | 41 /32.0 | ////////// |
| * | -Gz | 92 /41.2 | 91 /37.8 | 31 /28.0 | 10 /40.0 | 44 /31.2 | 1.375 |

Negative "G" Restraint Data Master
Raw Data

Subject I.D. - B Restraint Type - VI

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /38.9 | 90.5/33.2 | 28 /28.4 | 09 /38.7 | 40 /32.7 | ////////// |
| * | +Gx | 93 /40.1 | 93 /35.8 | 31 /27.5 | 10 /37.8 | 43 /31.3 | ////////// |
| * | -Gz | 93 /40.8 | 93 /36.9 | 31 /28.8 | 10 /37.9 | 45 /30.6 | 0.875 |
| 2 | +Gz | 92 /38.5 | 90.5/33.1 | 29 /28.0 | 09 /38.6 | 41 /32.7 | ////////// |
| * | +Gx | 92.5/40.1 | 93 /35.4 | 31.5/27.1 | 10 /37.3 | 44 /31.2 | ////////// |
| * | -Gz | 93 /40.8 | 93 /36.9 | 32 /28.7 | 10 /37.7 | 46 /30.4 | 875 |
| 3 | +Gz | 91.5/38.4 | 90 /32.9 | 29 /28.2 | 10 /38.5 | 41 /32.4 | ////////// |
| * | +Gx | 92.5/40.1 | 93 /35.3 | 31 /27.3 | 10 /37.2 | 43 /31.6 | ////////// |
| * | -Gz | 93 /41.1 | 92 /36.9 | 31 /28.7 | 10 /38.0 | 45 /30.8 | 1.00 |
| 4 | +Gz | 91.5/38.6 | 90 /32.9 | 29 /28.1 | 09 /38.3 | 39 /33.2 | ////////// |
| * | +Gx | 92.5/40.1 | 93 /35.6 | 32 /27.1 | 10 /37.0 | 44 /31.0 | ////////// |
| * | -Gz | 93 /40.7 | 92 /37.1 | 32 /28.7 | 10 /37.9 | 46 /30.6 | 0.75 |
| 5 | +Gz | 92 /38.6 | 90 /33.1 | 29 /28.2 | 09 /39.7 | 40 /32.5 | ////////// |
| * | +Gx | 92.5/40.2 | 93 /35.6 | 31 /27.2 | 09.5/37.5 | 42 /30.9 | ////////// |
| * | -Gz | 93 /41.2 | 92 /37.4 | 31 /28.7 | 10 /38.1 | 45 /30.7 | 1.00 |

Negative "G" Restraint Data Master
Raw Data

Subject I.D. - L          Restraint Type - I

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /39.4 | 90.5/33.4 | 28 /29.3 | 09 /43.2 | 38 /33.7 | ////////// |
| * | +Gx | 92 /40.6 | 91 /35.3 | 29 /28.2 | 10 /41.8 | 40 /33.1 | ////////// |
| * | -Gz | 92 /41.9 | 91 /36.9 | 30 /29.1 | 09 /42.4 | 38 /33.2 | 1.6 |
| 2 | +Gz | 92 /39.8 | 90.5/33.8 | 29 /28.9 | 09 /42.8 | 37 /33.9 | ////////// |
| * | +Gx | 92 /40.8 | 91.5/35.4 | 30 /28.0 | 09 /41.5 | 41 /32.4 | ////////// |
| * | -Gz | 92 /42.1 | 92 /37.4 | 30 /28.8 | 09 /41.8 | 41 /32.1 | 1.0 |
| 3 | +Gz | 92 /39.8 | 90.5/33.8 | 29 /28.8 | 09 /42.6 | 39 /33.1 | ////////// |
| * | +Gx | 93 /41.1 | 92 /36.3 | 30 /28.0 | 09 /41.8 | 40 /32.5 | ////////// |
| * | -Gz | 92 /42.1 | 92 /37.5 | 30 /28.9 | 09 /41.5 | 43 /31.5 | 1.0 |
| 4 | +Gz | 92 /39.6 | 90.5/34.1 | 29 /29.0 | 09 /42.8 | 38 /33.7 | ////////// |
| * | +Gx | 92 /40.9 | 92 /35.8 | 31 /28.0 | 09 /41.3 | 41 /32.4 | ////////// |
| * | -Gz | 92 /42.1 | 92 /37.5 | 30 /28.9 | 09 /41.6 | 42 /32.0 | 1.25 |
| 5 | +Gz | 92 /39.7 | 90.5/33.5 | 28 /29.4 | 09 /43.5 | 37 /33.7 | ////////// |
| * | +Gx | 92 /40.7 | 92 /35.5 | 30 /28.0 | 09 /41.7 | 41 /32.1 | ////////// |
| * | -Gz | 92 /42.2 | 92 /37.5 | 30 /28.8 | 09 /42.0 | 42 /32.0 | 1.4 |

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /39.4 | 91 /33.1 | 28 /29.4 | 08 /42.9 | 36 /34.5 | ////////// |
| * | +Gx | 92 /40.4 | 93 /35.7 | 31 /27.7 | 09 /40.7 | 41 /32.2 | ////////// |
| * | -Gz | 92 /41.8 | 93 /37.4 | 31 /28.2 | 08 /40.8 | 41 /32.0 | 1.0 |
| 2 | +Gz | 92 /39.7 | 91 /33.5 | 29 /28.6 | 08 /42.2 | 38 /33.4 | ////////// |
| * | +Gx | 92 /41.0 | 92 /35.5 | 31 /27.7 | 09 /40.3 | 41 /32.2 | ////////// |
| * | -Gz | 93 /41.9 | 93 /37.4 | 36 /28.0 | 08 /40.4 | 44 /31.3 | 0.55 |
| 3 | +Gz | 92 /39.5 | 90.5/33.0 | 29 /28.8 | 08 /42.5 | 37 /33.6 | ////////// |
| * | +Gx | 92 /40.7 | 93 /35.5 | 31 /27.7 | 09 /40.5 | 41 /32.6 | ////////// |
| * | -Gz | 93 /41.9 | 93 /37.7 | 31 /26.0 | 08 /40.4 | 45 /30.9 | 1.2 |
| 4 | +Gz | 92 /39.6 | 91 /33.3 | 30 /28.8 | 08 /42.3 | 38 /33.4 | ////////// |
| * | +Gx | 92 /40.7 | 92 /36.0 | 31 /27.6 | 09 /40.3 | 40 /32.7 | ////////// |
| * | -Gz | 93 /41.7 | 93 /37.9 | 32 /28.4 | 09 /40.0 | 41 /32.2 | 1.1 |
| 5 | +Gz | 92 /39.5 | 91 /33.2 | 29 /28.7 | 08 /42.3 | 38 /33.5 | ////////// |
| * | +Gx | 92 /40.8 | 92 /35.4 | 31 /27.6 | 09 /40.5 | 40 /32.7 | ////////// |
| * | -Gz | 93 /41.9 | 93 /37.7 | 31 /28.2 | 08 /40.3 | 42 /31.5 | 0.8 |

Negative "G" Restraint Data Master
Raw Data

Subject I.D. - L    Restraint Type - II.

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /38.9 | 90 /33.0 | 29 /29.6 | 09 /42.9 | 37 /33.7 | ////////// |
| * | +Gx | 92 /39.9 | 91 /34.9 | 31 /28.7 | 10 /41.9 | 40 /32.7 | ////////// |
| * | -Gz | 92 /40.3 | 91 /36.0 | 31 /29.8 | 09 /41.8 | 39 /32.8 | 0.2 |
| 2 | +Gz | 91.5/39.0 | 90.5/33.4 | 29 /29.5 | 09 /43.0 | 38 /33.6 | ////////// |
| * | +Gx | 92 /40.0 | 92 /35.4 | 31 /28.7 | 10 /41.9 | 42 /32.3 | ////////// |
| * | -Gz | 92.5/40.4 | 91 /36.2 | 32 /30.0 | 10 /41.7 | 39 /33.0 | 0.4 |
| 3 | +Gz | 91.5/39.0 | 90.5/33.2 | 29 /29.6 | 09 /43.0 | 38 /33.7 | ////////// |
| * | +Gx | 92 /40.0 | 92 /35.3 | 30 /28.7 | 10 /42.2 | 40 /32.9 | ////////// |
| * | -Gz | 92.5/40.6 | 91.5/36.1 | 32 /29.9 | 10 /41.7 | 40 /32.9 | 0.5 |
| 4 | +Gz | 91.5/39.2 | 90.5/33.2 | 29 /29.3 | 09 /43.2 | 38 /33.6 | ////////// |
| * | +Gx | 92 /40.2 | 92 /35.2 | 31 /28.6 | 10 /42.0 | 41 /32.6 | ////////// |
| * | -Gz | 92 /40.6 | 91.5/36.3 | 31 /28.9 | 10 /42.0 | 40 /32.7 | 0.6 |
| 5 | +Gz | 92 /39.2 | 90.5/33.2 | 29 /29.5 | 09 /43.3 | 38 /33.6 | ////////// |
| * | +Gx | 92 /40.1 | 92 /35.4 | 31 /28.6 | 10 /41.8 | 41 /32.2 | ////////// |
| * | -Gz | 92 /40.5 | 91 /36.1 | 31 /29.8 | 10 /41.8 | 40 /32.7 | 0.5 |

Negative "G" Restraint Data Master
Raw Data

Subject I.D. - L    Restraint Type - III

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /39.3 | 90 /33.3 | 29 /29.5 | 10 /42.6 | 37 /33.7 | ////////// |
| * | +Gx | 92.5/40.4 | 92.5/35.5 | 31 /28.7 | 10 /41.8 | 38 /33.2 | ////////// |
| * | -Gz | 93 /40.8 | 92 /36.1 | 32 /29.7 | 10 /41.0 | 40 /32.8 | 0.3 |
| 2 | +Gz | 92.5/39.2 | 90 /33.0 | 29 /29.8 | 09 /43.1 | 37 /33.6 | ////////// |
| * | +Gx | 93 /40.1 | 92.5/35.3 | 31 /29.0 | 10 /41.7 | 40 /32.7 | ////////// |
| * | -Gz | 92.5/40.4 | 92.5/36.2 | 33 /30.2 | 10 /41.0 | 39 /33.2 | 0.25 |
| 3 | +Gz | 92.5/39.1 | 91 /33.8 | 29 /29.8 | 09 /43.0 | 38 /33.3 | ////////// |
| * | +Gx | 92.5/40.3 | 92.5/36.0 | 31 /28.9 | 09 /41.7 | 40 /32.7 | ////////// |
| * | -Gz | 92.5/40.7 | 92.5/36.8 | 33 /30.2 | 10 /41.0 | 41 /32.3 | 0.35 |
| 4 | +Gz | 92 /39.3 | 90.5/33.0 | 29 /29.6 | 09 /42.9 | 37 /33.9 | ////////// |
| * | +Gx | 93 /40.4 | 93 /36.3 | 31 /28.8 | 10 /41.4 | 40 /32.9 | ////////// |
| * | -Gz | 92.5/40.7 | 93 /36.6 | 32 /30.1 | 09 /41.2 | 39 /32.9 | 0.3 |
| 5 | +Gz | 92 /39.3 | 91 /33.5 | 29 /29.7 | 09 /43.0 | 37 /33.6 | ////////// |
| * | +Gx | 92.5/40.3 | 93 /36.6 | 31 /28.8 | 10 /41.5 | 39 /33.0 | ////////// |
| * | -Gz | 92.5/40.5 | 92 /36.6 | 31 /31.0 | 10 /40.9 | 40 /32.4 | 0.3 |

Negative "G" Restraint Data Master
Raw Data

Subject I.D. - L Restraint Type - IV

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /39.4 | 90 /33.4 | 27 /29.3 | 08 /42.6 | 38 /33.9 | ////////// |
| * | +Gx | 93 /40.5 | 92.5/35.7 | 29 /28.7 | 09 /42.0 | 40 /32.6 | ////////// |
| * | -Gz | 92.5/40.9 | 91 /36.8 | 30 /29.3 | 08 /42.1 | 42 /31.8 | 0.5 |
| 2 | +Gz | 92 /39.5 | 90.5/33.3 | 28 /29.4 | 07 /42.6 | 38 /33.5 | ////////// |
| * | +Gx | 92.5/40.3 | 92.5/35.2 | 29 /28.9 | 09 /42.1 | 40 /32.9 | ////////// |
| * | -Gz | 92 /41.0 | 91 /36.7 | 30 /29.5 | 08 /42.2 | 42 /32.1 | 0.7 |
| 3 | +Gz | 92 /39.3 | 91 /33.4 | 28 /29.4 | 07 /42.8 | 37 /33.4 | ////////// |
| * | +Gx | 92.5/40.0 | 92 /35.3 | 30 /29.0 | 08 /42.2 | 40 /32.6 | ////////// |
| * | -Gz | 92 /41.1 | 91 /36.6 | 30 /29.4 | 08 /42.3 | 43 /31.9 | 0.9 |
| 4 | +Gz | 92 /39.4 | 91.5/33.6 | 27 /29.4 | 07 /42.7 | 37 /33.4 | ////////// |
| * | +Gx | 92 /40.3 | 92 /35.3 | 29 /28.9 | 09 /42.1 | 41 /32.5 | ////////// |
| * | -Gz | 92 /41.1 | 90.5/36.8 | 30 /29.4 | 08 /42.1 | 41 /32.2 | 1.0 |
| 5 | +Gz | 92 /39.4 | 90.5/33.4 | 28 /29.3 | 07 /42.8 | 38 /33.5 | ////////// |
| * | +Gx | 92.5/40.4 | 93 /35.3 | 29 /28.8 | 09 /42.2 | 41 /32.4 | ////////// |
| * | -Gz | 92 /41.3 | 91 /36.4 | 30 /29.4 | 09 /42.3 | 42 /32.0 | 1.0 |

Negative "G" Restraint Data Master
Raw Data

Subject I.D. - L Restraint Type - V

Negative "G" Restraint Data Master

Raw Data

Subject I.D. - L          Restraint Type - VI

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /38.8 | 91 /33.0 | 27 /30.0 | 08 /43.3 | 37 /33.6 | ////////// |
| * | +Gx | 93 /40.1 | 92 /35.7 | 28 /29.2 | 09 /42.5 | 39 /33.0 | ////////// |
| * | -Gz | 92.5/40.8 | 91 /36.4 | 28 /30.2 | 08 /42.6 | 39 /32.9 | 0.5 |
| 2 | +Gz | 92 /39.1 | 90.5/33.1 | 27 /29.8 | 08 /43.3 | 38 /33.4 | ////////// |
| * | +Gx | 93 /40.0 | 93 /35.8 | 29 /29.2 | 09 /42.6 | 39 /33.1 | ////////// |
| * | -Gz | 92.5/40.8 | 91 /36.6 | 29 /30.2 | 08 /42.7 | 41 /32.1 | 0.3 |
| 3 | +Gz | 92 /39.1 | 90.5/33.0 | 27 /29.9 | 08 /43.2 | 37 /34.0 | ////////// |
| * | +Gx | 93 /40.2 | 93 /35.2 | 29 /29.2 | 09 /42.4 | 40 /32.8 | ////////// |
| * | -Gz | 92.5/40.8 | 92 /37.5 | 30 /29.9 | 09 /42.4 | 41 /32.1 | 0.5 |
| 4 | +Gz | 92 /39.1 | 90 /33.2 | 27 /29.7 | 08 /43.0 | 37 /33.7 | ////////// |
| * | +Gx | 93 /40.1 | 92 /35.6 | 28 /28.8 | 08 /42.0 | 39 /32.9 | ////////// |
| * | -Gz | 92.5/40.8 | 91 /37.6 | 30 /29.9 | 08 /42.2 | 40 /32.4 | 0.6 |
| 5 | +Gz | 92 /39.1 | 90.5/33.0 | 27 /29.5 | 07 /42.9 | 38 /33.4 | ////////// |
| * | +Gx | 93 /40.3 | 92 /35.4 | 28 /28.9 | 08 /42.1 | 40 /32.9 | ////////// |
| * | -Gz | 92.5/40.9 | 91 /36.6 | 30 /29.8 | 08 /42.0 | 41 /32.4 | 0.5 |

Negative "G" Restraint Data Master
Raw Data
Subject I.D. - P    Restraint Type - I

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /38.0 | 90 /31.7 | 32 /27.0 | 10 /37.5 | 42 /32.5 | ////////// |
| * | +Gx | 92 /39.6 | 92 /33.7 | 35 /26.3 | 11 /36.3 | 43 /31.8 | ////////// |
| * | -Gz | 92 /42.2 | 92 /36.3 | 36 /26.0 | 11 /34.9 | 43 /31.5 | 2.0 |
| 2 | +Gz | 92 /38.5 | 91 /31.4 | 34 /27.8 | 10 /36.7 | 41 /32.6 | ////////// |
| * | +Gx | 92 /39.5 | 92 /33.5 | 35 /26.5 | 11 /35.9 | 41 /32.1 | ////////// |
| * | -Gz | 93 /41.9 | 92 /36.2 | 36 /26.1 | 11 /35.4 | 45 /31.0 | 1.5 |
| 3 | +Gz | 92 /38.2 | 91 /31.5 | 34 /27.7 | 11 /36.6 | 40 /32.8 | ////////// |
| * | +Gx | 92 /39.6 | 92 /33.6 | 36 /26.7 | 11 /35.7 | 42 /32.0 | ////////// |
| * | -Gz | 93 /41.9 | 92 /36.4 | 36 /25.9 | 11 /35.0 | 43 /31.6 | 2.5 |
| 4 | +Gz | 92 /38.5 | 91 /31.6 | 34 /27.4 | 11 /36.7 | 41 /32.7 | ////////// |
| * | +Gx | 92 /39.9 | 92 /33.9 | 35 /26.5 | 11 /35.8 | 42 /32.0 | ////////// |
| * | -Gz | 93 /42.0 | 92 /36.2 | 36 /26.0 | 11 /34.9 | 43 /31.4 | 2.125 |
| 5 | +Gz | | | | | | ////////// |
| * | +Gx | | | | | | ////////// |
| * | -Gz | | | | | | |

Negative "G" Restraint Data Master
Raw Data
Subject I.D. - P          Restraint Type - II

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /38.2 | 90.5/31.4 | 33 /27.5 | 09 /37.2 | 40 /32.6 | ////////// |
| * | +Gx | 93 /39.5 | 93 /33.4 | 36 /26.7 | 09 /35.6 | 42 /31.9 | ////////// |
| * | -Gz | 93 /41.4 | 92 /34.7 | 37 /26.6 | 09 /34.8 | 43 /31.5 | 2.375 |
| 2 | +Gz | 92 /38.6 | 90.5/31.3 | 35 /27.4 | 09 /36.2 | 41 /32.3 | ////////// |
| * | +Gx | 93 /39.6 | 93 /33.7 | 36 /26.5 | 09 /35.4 | 42 /31.7 | ////////// |
| * | -Gz | 93 /41.6 | 93 / 35.3 | 37 /26.5 | 10 /34.4 | 43 /30.9 | 2.25 |
| 3 | +Gz | 92 /38.4 | 90.5/31.4 | 35 /27.6 | 09 /35.9 | 39 /33.0 | ////////// |
| * | +Gx | 93 /39.8 | 93 /33.8 | 36 /26.5 | 10/ 35.2 | 42 /31.7 | ////////// |
| * | -Gz | 93 /41.7 | 92 /35.7 | 37 /26.6 | 10/ 34.3 | 44 /31.3 | 2.5 |
| 4 | +Gz | 92 /38.5 | 90.5/31.2 | 35 /27.6 | 09 /35.9 | 41 /32.3 | ////////// |
| * | +Gx | 93 /40.4 | 93 /33.7 | 36 /26.3 | 10 /35.2 | 43 /31.5 | ////////// |
| * | -Gz | 93 /42.1 | 92.5/36.3 | 37 /26.2 | 10 /34.6 | 43 /31.2 | 2.25 |
| 5 | +Gz | 92 /38.4 | 90.5/31.7 | 36 /27.6 | 09 /35.4 | 41 /32.2 | ////////// |
| * | +Gx | 93 /40.2 | 93 /34.4 | 36 /26.4 | 10 /35.3 | 43 /31.6 | ////////// |
| * | -Gz | 93 /41.9 | 92.5/35.3 | 37 /26.8 | 10 /34.4 | 45 /30.8 | 2.175 |

Negative "G" Restraint Data Master
Raw Data
Subject I.D. - P Restraint Type - III

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92.5/38.5 | 92 /31.6 | 34 /27.5 | 09 /36.1 | 41 /32.4 | ////////// |
| * | +Gx | 93 /39.4 | 93.5/33.2 | 36/ 27.0 | 10 /35.2 | 41 /32.4 | ////////// |
| * | -Gz | 93 /40.2 | 92 /34.2 | 36 /27.9 | 10 /35.4 | 41 /32.2 | 0.6 |
| 2 | +Gz | 92.5/38.4 | 91.5/31.5 | 34 /27.6 | 09 /35.4 | 40 /32.8 | ////////// |
| * | +Gx | 93 /39.5 | 94 /33.6 | 36 /27.0 | 10 /34.8 | 42 /31.9 | ////////// |
| * | -Gz | 93 /40.4 | 92 /34.5 | 36 /27.7 | 09 /35.5 | 41 /32.2 | 1.0 |
| 3 | +Gz | 93 /38.8 | 92 /31.9 | 35 /27.6 | 09 /35.4 | 39 /33.0 | ////////// |
| * | +Gx | 93 /39.6 | 94 /33.7 | 35 /26.8 | 10 /35.4 | 42 /32.0 | ////////// |
| * | -Gz | 92.5/40.5 | 92.5/35.0 | 35 /27.5 | 10 /35.7 | 42 /31.8 | 0.9 |
| 4 | +Gz | 92.5/38.6 | 91.5/31.6 | 33 /27.4 | 09 /35.7 | 41 /32.3 | ////////// |
| * | +Gx | 93 /39.5 | 93 /33.2 | 36 /26.8 | 10 /35.1 | 41 /32.1 | ////////// |
| * | -Gz | 93 /40.4 | 93 / 34.8 | 35 /27.5 | 10 /35.2 | 41 /32.1 | 1.0 |
| 5 | +Gz | 92.5/38.7 | 92 /31.8 | 35 /27.7 | 10 /35.3 | 41 /32.3 | ////////// |
| * | +Gx | 93 /39.6 | 93.5/33.5 | 36 /26.8 | 10 /35.2 | 43 /31.8 | ////////// |
| * | -Gz | 93 /40.5 | 92.5/34.7 | 35 /27.5 | 09 /35.5 | 42 /31.6 | 1.0 |

Negative "G" Restraint Data Master
Raw Data
Subject I.D. - P          Restraint Type - IV

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /37.9 | 91 /30.9 | 34 /27.7 | 09 /36.4 | 40 /32.7 | ////////// |
| * | +Gx | 93 /39.0 | 94 /33.7 | 36 /27.0 | 09 /35.6 | 41 /32.1 | ////////// |
| * | -Gz | 93 /39.4 | 92 /33.7 | 36 /27.8 | 10 /35.0 | 41 /32.1 | 0.4 |
| 2 | +Gz | 92 /38.2 | 91.5/31.2 | 34 /27.7 | 09 /35.8 | 40 /32.9 | ////////// |
| * | +Gx | 93 /38.9 | 94 /32.8 | 36 /26.9 | 09 /35.0 | 41 /32.1 | ////////// |
| * | -Gz | 93 /39.6 | 93 /34.3 | 37 /27.9 | 10 /35.1 | 42 /31.8 | 0.2 |
| 3 | +Gz | 92 /38.2 | 91 /31.2 | 35 /27.7 | 09 /35.4 | 40 /33.1 | ////////// |
| * | +Gx | 93 /39.0 | 94 /33.4 | 36 /26.9 | 09 /35.2 | 40 /32.6 | ////////// |
| * | -Gz | 93 /39.6 | 92 /34.1 | 37 /27.8 | 10 /35.3 | 41 /32.2 | 0.3 |
| 4 | +Gz | 92 /38.2 | 91.5/31.2 | 36 /27.7 | 09 /35.8 | 38 /33.3 | ////////// |
| * | +Gx | 93 /39.2 | 94 /33.5 | 36 /26.8 | 09 /35.5 | 42 /32.1 | ////////// |
| * | -Gz | 93 /39.6 | 92 /33.9 | 37 /27.9 | 10 /34.9 | 41 /32.2 | 0.4 |
| 5 | +Gz | 92 /38.1 | 91.5/31.2 | 35 /27.7 | 09 /35.7 | 40 /32.9 | ////////// |
| * | +Gx | 93 /39.4 | 94 /33.8 | 36 /26.7 | 09 /35.6 | 40 /32.5 | ////////// |
| * | -Gz | 93 /39.7 | 92 /34.0 | 36 /27.7 | 10 /35.4 | 44 /31.1 | 0.3 |

Negative "G" Restraint Data Master
Raw Data
Subject I.D. - P          Restraint Type - V

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /38.2 | 91.5/31.8 | 31 /27.1 | 08 /38.0 | 38 /33.1 | ////////// |
| * | +Gx | 93 /39.4 | 93.5/33.6 | 31 /26.5 | 09 /37.5 | 41 /32.4 | ////////// |
| * | -Gz | 92 /40.1 | 91 /35.1 | 32 /27.0 | 10 /38.1 | 41 /32.4 | 0.7 |
| 2 | +Gz | 92 /38.5 | 91.5/31.4 | 31 /27.1 | 08 /38.0 | 39 /33.1 | ////////// |
| * | +Gx | 93 /39.4 | 93.5/33.8 | 31 /26.6 | 09 /37.6 | 41 /32.5 | ////////// |
| * | -Gz | 92.5/40.2 | 90.5/35.7 | 32 /27.1 | 09 /37.9 | 41 /32.1 | 1.3 |
| 3 | +Gz | 92.5/38.4 | 91 /31.2 | 31 /27.2 | 09 /37.8 | 39 /33.0 | ////////// |
| * | +Gx | 93 /39.4 | 94 /33.3 | 32 /26.6 | 10 /37.7 | 42 /32.2 | ////////// |
| * | -Gz | 92. /40.4 | 91 /35.7 | 32 /27.3 | 09 /37.9 | 40 /32.4 | 1.5 |
| 4 | +Gz | 92.5/38.5 | 91.5/31.1 | 31 /27.2 | 09 /37.8 | 39 /32.9 | ////////// |
| * | +Gx | 93 /39.3 | 93 /33.9 | 32 /26.6 | 10 /37.7 | 42 /32.1 | ////////// |
| * | -Gz | 92.5/40.4 | 91 /35.5 | 33 /27.2 | 09 /37.8 | 42 /32.1 | 1.4 |
| 5 | +Gz | 92.5/38.4 | 91.5/31.3 | 30 /27.1 | 09 /38.3 | 40 /33.0 | ////////// |
| * | +Gx | 93 /39.2 | 94 /33.5 | 31 /26.6 | 10 /38.2 | 42 /32.1 | ////////// |
| * | -Gz | 92 /40.3 | 91 /36.2 | 32 /27.1 | 10 /38.6 | 41 /32.1 | 1.5 |

Negative "G" Restraint Data Master
Raw Data
Subject I.D. - P          Restraint Type - VI

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92.5/38.1 | 91.5/31.1 | 30 /27.3 | 08 /38.5 | 39 /33.1 | ////////// |
| * | +Gx | 93 /38.8 | 93.5/32.7 | 31 /26.9 | 08 /38.2 | 40 /32.7 | ////////// |
| * | -Gz | 92.5/39.3 | 91.5/35.0 | 32 /27.3 | 08 /38.5 | 41 /32.5 | 0.6 |
| 2 | +Gz | 92.5/38.1 | 91.5/30.9 | 31 /27.4 | 07 /38.4 | 40 /33.1 | ////////// |
| * | +Gx | 93 /39.0 | 94 /33.4 | 31 /26.8 | 08 /38.0 | 42 /32.4 | ////////// |
| * | -Gz | 92.5/39.6 | 91 /34.6 | 32 /27.2 | 08 /38.5 | 40 /32.7 | 1.2 |
| 3 | +Gz | 92.5/38.1 | 91 /31.3 | 30 /27.5 | 08 /38.6 | 39 /33.4 | ////////// |
| * | +Gx | 93 /38.9 | 94 /33.7 | 31 /26.9 | 08 /38.2 | 40 /32.8 | ////////// |
| * | -Gz | 92.5/39.5 | 91.5/35.1 | 31 /27.2 | 08 /38.6 | 40 /32.7 | 1.0 |
| 4 | +Gz | 92.5/38.0 | 91 /31.0 | 30 /27.5 | 08 /38.2 | 40 /32.7 | ////////// |
| * | +Gx | 93 /39.0 | 94 /33.6 | 31 /27.0 | 09 /38.0 | 41 /32.5 | ////////// |
| * | -Gz | 92.5/39.6 | 91.5/35.0 | 32 /27.2 | 09 /38.4 | 39 /33.0 | 1.5 |
| 5 | +Gz | 92.5/38.0 | 91 /31.0 | 30 /27.5 | 08 /38.4 | 39 /33.3 | ////////// |
| * | +Gx | 93 /39.0 | 94 /33.3 | 31 /26.8 | 09 /38.0 | 40 /32.8 | ////////// |
| * | -Gz | 92.5/39.6 | 91 /35.1 | 32 /27.0 | 09 /38.2 | 40 /32.6 | 1.1 |

Negative "G" Restraint Data Master
Raw Data

Subject I.D. - R          Restraint Type - I

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /37.6 | 91 /31.2 | 32 /27.3 | 10 /38.0 | 39 /33.2 | ////////// |
| * | +Gx | 92 /40.2 | 91 /33.8 | 34 /25.2 | 11 /36.7 | 42 /31.9 | ////////// |
| * | -Gz | 92 /41.0 | 93 /35.0 | 35 /25.4 | 11 /36.4 | 43 /30.5 | 2.0 |
| 2 | +Gz | 93 /37.8 | 91 /31.5 | 32 /26.9 | 11 /38.2 | 40 /32.8 | ////////// |
| * | +Gx | 93 /39.0 | 93 /33.9 | 34 /25.9 | 10 /37.1 | 43 /31.4 | ////////// |
| * | -Gz | 93 /40.8 | 92 /35.0 | 34 /25.7 | 11 /36.5 | 45 /30.8 | 1.5 |
| 3 | +Gz | 92 /37.8 | 91 /31.3 | 33 /26.7 | 11 /37.7 | 40 /32.7 | ////////// |
| * | +Gx | 93 /39.4 | 92 /33.9 | 34 /25.5 | 11 /36.7 | 44 /31.4 | ////////// |
| * | -Gz | 93 /41.0 | 93 /35.0 | 35 /25.8 | 11 /36.4 | 44 /30.8 | 1.5 |
| 4 | +Gz | 92 /37.9 | 91 /31.0 | 33 /26.6 | 11 /37.5 | 40 /33.0 | ////////// |
| * | +Gx | 92 /39.6 | 92 /34.1 | 34 /25.5 | 10 /36.8 | 42 /31.8 | ////////// |
| * | -Gz | 93 /41.1 | 93 /35.0 | 35 /25.7 | 11 /36.0 | 45 /30.7 | 1.875 |
| 5 | +Gz | 92 / 37.6 | 91 /31.5 | 33 /26.9 | 11 /38.1 | 38 /33.5 | ////////// |
| * | +Gx | 93 /39.5 | 92 /33.8 | 35 /25.6 | 11 /36.3 | 43 /31.9 | ////////// |
| * | -Gz | 93 /41.3 | 93 /35.5 | 35 /25.4 | 11 /35.8 | 45 /30.8 | 2.125 |

Negative "G" Restraint Data Master
Raw Data
Subject I.D. - R          Restraint Type - II

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92.5/37.6 | 90 /32.2 | 32 /27.3 | 09 /37.4 | 38 /33.3 | ////////// |
| * | +Gx | 93 /38.9 | 91.5/34.0 | 34 /26.4 | 10 /36.4 | 41 /32.2 | ////////// |
| * | -Gz | 92.5/39.9 | 90.5/34.7 | 33 /26.6 | 09 /36.5 | 40 /32.5 | 1.0 |
| 2 | +Gz | 92 /37.8 | 90 /32.4 | 33 /27.2 | 09 /37.3 | 39 /33.0 | ////////// |
| * | +Gx | 93 /39.1 | 92 /35.4 | 35 /26.3 | 10 /36.4 | 43 /31.7 | ////////// |
| * | -Gz | 92.5/40.4 | 91 /35.4 | 35 /26.4 | 09 /36.2 | 41 /32.0 | 1.0 |
| 3 | +Gz | 92.5/37.7 | 90 /32.1 | 33 /27.2 | 08 /37.3 | 38 /33.3 | ////////// |
| * | +Gx | 92.5/38.7 | 91.5/34.5 | 36 /26.6 | 10 /36.1 | 41 /32.5 | ////////// |
| * | -Gz | 92 /40.3 | 91 /35.4 | 33 /26.2 | 08 /36.1 | 40 /32.5 | 0.9 |
| 4 | +Gz | 92.5/37.5 | 90 /32.4 | 33 /27.2 | 09 /37.1 | 38 /33.4 | ////////// |
| * | +Gx | 93 /38.9 | 91.5/34.5 | 35 /26.4 | 10 /36.3 | 41 /32.3 | ////////// |
| * | -Gz | 92.5/40.3 | 90.5/35.2 | 34 /26.2 | 09 /36.2 | 42 /31.6 | 1.0 |
| 5 | +Gz | 92.5/37.7 | 90 /32.7 | 34 /27.1 | 09 /37.0 | 39 /33.1 | ////////// |
| * | +Gx | 92.5/39.1 | 91 /34.3 | 35 /26.3 | 10 /36.2 | 41 /32.4 | ////////// |
| * | -Gz | 92 /40.2 | 90.5/35.4 | 34 /26.4 | 09 /35.8 | 41 /32.0 | 0.9 |

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /37.3 | 90 /32.5 | 33 /27.5 | 10 /38.1 | 40 /32.8 | ////////// |
| * | +Gx | 93 /38.1 | 91 /33.1 | 36 /26.7 | 10 /36.7 | 43 /31.6 | ////////// |
| * | -Gz | 92 /39.1 | 91 /34.7 | 36 /27.3 | 10 /36.7 | 42 /32.2 | 0.875 |
| 2 | +Gz | 92 /37.4 | 90 /32.5 | 35 /26.9 | 10 /37.5 | 40 /32.7 | ////////// |
| * | +Gx | 93 /38.2 | 92 /33.7 | 35 /26.1 | 10 /36.9 | 42 /31.8 | ////////// |
| * | -Gz | 93 /39.3 | 91 /34.5 | 35 /27.1 | 10 /37.0 | 44 /31.6 | 0.625 |
| 3 | +Gz | 92 /37.5 | 90 /32.4 | 35 /26.9 | 10 /37.5 | 41 /32.8 | ////////// |
| * | +Gx | 93 /38.5 | 92 /34.5 | 35 /26.2 | 10 /36.6 | 41 /32.1 | ////////// |
| * | -Gz | 93 /39.5 | 91 /34.5 | 35 /27.1 | 10 /37.4 | 42 /32.0 | 0.5 |
| 4 | +Gz | 92 /37.4 | 90 /32.2 | 34 /27.1 | 10 /37.7 | 41 /32.6 | ////////// |
| * | +Gx | 93 /38.5 | 92 /33.9 | 35 /26.3 | 10 /36.6 | 42 /31.9 | ////////// |
| * | -Gz | 93 /39.3 | 91 /34.7 | 35 /27.1 | 10 /36.9 | 42 /32.0 | 0.75 |
| 5 | +Gz | 92 /37.5 | 90 /32.6 | 33 /27.0 | 10 /38.0 | 40 /32.6 | ////////// |
| * | +Gx | 93 /38.5 | 92 /34.0 | 35 /26.3 | 10 /36.7 | 42 /31.9 | ////////// |
| * | -Gz | 93 /39.4 | 91 /34.8 | 35 /26.7 | 10 /37.5 | 42 /32.2 | 0.875 |

Negative "G" Restraint Data Master

Raw Data

Subject I.D. - R          Restraint Type - III

Negative "G" Restraint Data Master
Raw Data

Subject I.D. - R    Restraint Type - IV

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /37.5 | 90 /32.3 | 34 /26.9 | 10 /37.6 | 40 /32.8 | ////////// |
| * | +Gx | 93 /38.8 | 92 /34.8 | 35 /36.1 | 10 /36.9 | 42 /32.0 | ////////// |
| * | -Gz | 92.5/39.6 | 91 /34.9 | 36 /26.8 | 10 /36.4 | 40 /32.4 | 0.625 |
| 2 | +Gz | 92 /37.5 | 90 /32.5 | 35 /26.8 | 09 /37.4 | 41 /32.7 | ////////// |
| * | +Gx | 93 /38.9 | 91.5/34.3 | 34 /25.9 | 10 /36.8 | 40 /32.2 | ////////// |
| * | -Gz | 93 /39.8 | 91 /34.6 | 35 /26.5 | 10 /36.5 | 41 /32.3 | 0.625 |
| 3 | +Gz | 92 /37.7 | 90 /31.6 | 34 /26.9 | 09 /37.8 | 38 /33.5 | ////////// |
| * | +Gx | 93 /38.5 | 91.5/33.9 | 35 /25.9 | 10 /37.2 | 42 /31.9 | ////////// |
| * | -Gz | 92 /39.4 | 91 /35.0 | 35 /26.4 | 10 /36.2 | 40 /32.7 | 0.375 |
| 4 | +Gz | 92 /37.5 | 90 /33.0 | 34 /27.0 | 09 /37.5 | 39 /33.1 | ////////// |
| * | +Gx | 93 /39.0 | 91 /34.7 | 35 /26.1 | 10 /36.5 | 41 /32.2 | ////////// |
| * | -Gz | 93 /39.8 | 91 /35.7 | 35 /26.6 | 10 /36.0 | 40 /32.6 | 0.625 |
| 5 | +Gz | 92 /37.7 | 90 /33.2 | 35 /26.9 | 10 /37.5 | 40 /32.7 | ////////// |
| * | +Gx | 93 /39.2 | 92 /34.6 | 36 /26.1 | 10 /36.5 | 43 /31.3 | ////////// |
| * | -Gz | 93 /39.9 | 91 /34.9 | 36 /26.7 | 10 /36.5 | 42 /31.9 | 0.625 |

Negative "G" Restraint Data Master
Raw Data
Subject I.D. - R          Restraint Type - V

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /37.2 | 90 /32.2 | 30 /27.6 | 09 /39.4 | 40 /32.8 | ////////// |
| * | +Gx | 93 /38.0 | 91.5/33.4 | 30 /27.0 | 09 /38.9 | 42 /32.2 | ////////// |
| * | -Gz | 92.5/39.2 | 91 /34.4 | 30 /27.4 | 10 /39.5 | 42 /31.7 | 1.1 |
| 2 | +Gz | 92 /37.6 | 90 /31.7 | 30 /27.6 | 08 /39.3 | 39 /32.9 | ////////// |
| * | +Gx | 92.5/38.4 | 91.5/33.5 | 30 /27.0 | 09 /38.9 | 41 /32.2 | ////////// |
| * | -Gz | 92.5/39.4 | 90.5/34.8 | 30 /27.3 | 09 /39.3 | 41 /32.1 | 1.0 |
| 3 | +Gz | 92.5/37.7 | 90 /32.9 | 29 /27.6 | 09 /39.5 | 40 /32.5 | ////////// |
| * | +Gx | 93 /38.8 | 91.5/33.8 | 30 /26.9 | 09 /38.9 | 42 /32.0 | ////////// |
| * | -Gz | 92.5/39.7 | 90.5/35.3 | 31 /27.4 | 10 /39.4 | 41 /32.2 | 1.2 |
| 4 | +Gz | 92 /37.7 | 90 /32.3 | 30 /27.4 | 08 /39.1 | 39 /32.9 | ////////// |
| * | +Gx | 92.5/38.7 | 91 /33.2 | 31 /26.8 | 09 /38.7 | 41 /32.3 | ////////// |
| * | -Gz | 93 /40.0 | 90.5/35.0 | 32 /26.8 | 09 /38.2 | 41 /32.2 | 1.3 |
| 5 | +Gz | 92 /37.4 | 90 /32.1 | 30 /27.4 | 08 /39.4 | 41 /32.4 | ////////// |
| * | +Gx | 92.5/38.5 | 91 /33.6 | 30 /26.8 | 09 /39.0 | 42 /31.7 | ////////// |
| * | -Gz | 92.5/39.8 | 90.5/35.0 | 31 /27.1 | 10 /39.3 | 42 /31.8 | 1.1 |

Negative "G" Restraint Data Master
Raw Data
Subject I.D. - R          Restraint Type - VI

| Run # | G Load | Head Ang/Dis | Shoulder Ang/Dis | Knee Ang/Dis | Foot Ang/Dis | Stick Ang/Dis | Off-Seat Distance |
|---|---|---|---|---|---|---|---|
| 1 | +Gz | 92 /36.9 | 90 /31.9 | 30 /27.7 | 09 /39.4 | 39 /33.2 | ////////// |
| * | +Gx | 93 /37.9 | 91 /33.6 | 31 /27.1 | 09 /39.0 | 40 /32.7 | ////////// |
| * | -Gz | 92 /39.0 | 90 /34.4 | 31 /27.4 | 09 /39.0 | 39 /32.9 | 0.375 |
| 2 | +Gz | 92 /36.7 | 90 /31.7 | 30 /27.7 | 08 /39.3 | 38 /33.5 | ////////// |
| * | +Gx | 93 /37.9 | 91 /33.4 | 31 /27.1 | 09 /38.9 | 40 /32.6 | ////////// |
| * | -Gz | 92 /39.2 | 90 /34.9 | 32 /27.3 | 10 /39.0 | 40 /32.7 | 0.5 |
| 3 | +Gz | 92 /37.0 | 90 /31.7 | 31 /27.7 | 08 /39.0 | 37 /34.1 | ////////// |
| * | +Gx | 93 /38.0 | 91 /34.2 | 31 /26.9 | 08 /38.4 | 41 /32.3 | ////////// |
| * | -Gz | 92 /39.0 | 90 /34.5 | 31 /27.2 | 09 /38.9 | 39 /33.0 | 0.375 |
| 4 | +Gz | 92 /37.0 | 90 /31.8 | 30 /27.7 | 08 /39.3 | 39 /33.2 | ////////// |
| * | +Gx | 93 /39.0 | 91 /33.3 | 31 /27.0 | 09 /38.8 | 40 /32.2 | ////////// |
| * | -Gz | 92 /39.3 | 90 /34.4 | 31 /27.2 | 10 /39.0 | 40 /32.7 | 0.375 |
| 5 | +Gz | 92 /36.9 | 90 /32.2 | 31 /27.6 | 08 /39.2 | 39 /33.2 | ////////// |
| * | +Gx | 93 /38.2 | 92 /33.9 | 31 /27.0 | 09 /38.7 | 41 /32.2 | ////////// |
| * | -Gz | 92 /39.4 | 90 /34.7 | 31 /27.1 | 10 /39.0 | 39 /32.9 | 0.4 |

DATA MASTER FROM LABORATORY STUDY
(CONVERTED DATA)

Negative "G" Restraint Data Master
Median Differences between Orientations
+Gz to -Gz
Restraint Type - I

| Subject | Axis | Head | Shoulder | Knee | Foot | Stick | Off-Seat |
|---|---|---|---|---|---|---|---|
| B | X | 0.6 | 0.1 | 1.5 | 1.7 | 4.2 | ////////// |
| * | Y | 3.8 | 4.7 | 0.4 | 0.3 | 1.2 | ////////// |
| * | Z | 3.8 | 4.7 | 1.6 | 1.7 | 4.3 | 2.4 |
| F | X | 0.1 | 0.1 | 1.7 | 2.0 | 2.3 | ////////// |
| * | Y | 3.9 | 4.3 | 0.1 | 0.3 | 1.3 | ////////// |
| * | Z | 3.9 | 4.3 | 1.7 | 2.0 | 2.7 | 2.6 |
| R | X | 0.8 | 1.3 | 1.4 | 1.7 | 3.4 | ////////// |
| * | Y | 3.2 | 3.8 | 0.2 | 0.3 | 0.6 | ////////// |
| * | Z | 3.3 | 4.0 | 1.5 | 1.7 | 3.4 | 1.9 |
| P | X | 0.9 | 0.7 | 1.8 | 1.8 | 1.8 | ////////// |
| * | Y | 3.7 | 4.7 | 0.0 | 0.0 | 0.2 | ////////// |
| * | Z | 3.8 | 4.8 | 1.8 | 1.8 | 1.8 | 2.0 |
| L | X | 0.1 | 1.0 | 0.3 | 1.1 | 2.7 | ////////// |
| * | Y | 2.5 | 3.6 | 0.5 | 0.2 | 0.8 | ////////// |
| * | Z | 2.5 | 3.8 | 0.6 | 1.1 | 2.8 | 1.3 |

Negative "G" Restraint Data Master
Median Differences between Orientations
+Gz to -Gz
Restraint Type - II

| Subject | Axis | Head | Shoulder | Knee | Foot | Stick | Off-Seat |
|---|---|---|---|---|---|---|---|
| B | X | 0.1 | 1.3 | 1.7 | 2.0 | 4.1 | ///////// |
| * | Y | 3.1 | 4.7 | 0.7 | 0.3 | 0.8 | ///////// |
| * | Z | 3.1 | 4.9 | 1.8 | 2.0 | 4.1 | 1.6 |
| F | X | 0.9 | 1.3 | 1.8 | 1.6 | 2.9 | ///////// |
| * | Y | 4.0 | 5.7 | 0.1 | 0.3 | 0.7 | ///////// |
| * | Z | 4.1 | 5.9 | 1.8 | 1.6 | 3.0 | 2.0 |
| R | X | 0.1 | 0.3 | 0.8 | 1.1 | 1.4 | ///////// |
| * | Y | 2.6 | 2.8 | 0.1 | 0.2 | 0.4 | ///////// |
| * | Z | 2.6 | 2.8 | 0.9 | 1.1 | 1.5 | 1.0 |
| P | X | 0.8 | 1.3 | 1.3 | 1.6 | 1.8 | ///////// |
| * | Y | 3.3 | 4.1 | 0.2 | 0.3 | 0.6 | ///////// |
| * | Z | 3.4 | 4.2 | 1.3 | 1.7 | 1.9 | 2.2 |
| L | X | 0.8 | 1.4 | 1.1 | 2.1 | 3.6 | ///////// |
| * | Y | 2.4 | 4.5 | 0.7 | 0.3 | 0.8 | ///////// |
| * | Z | 2.5 | 4.7 | 1.3 | 2.1 | 3.7 | 1.0 |

Negative "G" Restraint Data Master
Median Differences between Orientations
+Gz to -Gz
Restraint Type - III

| Subject | Axis | Head | Shoulder | Knee | Foot | Stick | Off-Seat |
|---|---|---|---|---|---|---|---|
| B | X | 0.1 | 0.7 | 0.6 | 0.5 | 2.8 | ///////// |
| * | Y | 2.7 | 4.1 | 0.3 | 0.1 | 0.4 | ///////// |
| * | Z | 2.7 | 4.2 | 0.7 | 0.5 | 2.8 | 1.0 |
| F | X | 0.1 | 0.7 | 0.7 | 0.6 | 1.3 | ///////// |
| * | Y | 2.2 | 5.1 | 0.1 | 0.6 | 0.5 | ///////// |
| * | Z | 2.2 | 5.2 | 0.7 | 0.8 | 1.4 | 0.6 |
| R | X | 0.8 | 0.6 | 0.2 | 0.5 | 1.0 | ///////// |
| * | Y | 1.9 | 2.2 | 0.4 | 0.1 | 0.5 | ///////// |
| * | Z | 2.1 | 2.3 | 0.5 | 0.5 | 1.1 | 0.8 |
| P | X | 0.4 | 0.4 | 0.2 | 0.1 | 0.8 | ///////// |
| * | Y | 1.8 | 3.0 | 0.9 | 0.5 | 0.0 | ///////// |
| * | Z | 1.9 | 3.0 | 0.9 | 0.5 | 0.8 | 1.0 |
| L | X | 0.4 | 0.6 | 0.3 | 1.4 | 1.4 | ///////// |
| * | Y | 1.4 | 2.9 | 1.1 | 0.5 | 0.4 | ///////// |
| * | Z | 1.5 | 3.0 | 1.1 | 1.5 | 1.4 | 0.5 |

Negative "G" Restraint Data Master
Median Differences between Orientations
+Gz to -Gz
Restraint Type - IV

| Subject | Axis | Head | Shoulder | Knee | Foot | Stick | Off-Seat |
|---|---|---|---|---|---|---|---|
| B | X | 0.1 | 1.4 | 1.0 | 1.4 | 2.2 | ////////// |
| * | Y | 2.4 | 4.6 | 1.1 | 0.2 | 0.4 | ////////// |
| * | Z | 2.4 | 4.9 | 1.5 | 1.4 | 2.3 | 0.6 |
| F | X | 0.1 | 0.7 | 0.8 | 1.4 | 2.2 | ////////// |
| * | Y | 2.2 | 4.5 | 1.7 | 0.5 | 0.9 | ////////// |
| * | Z | 2.2 | 4.6 | 1.9 | 1.4 | 2.3 | 0.8 |
| R | X | 0.8 | 0.6 | 0.6 | 1.2 | 0.7 | ////////// |
| * | Y | 2.2 | 2.6 | 0.2 | 0.4 | 0.1 | ////////// |
| * | Z | 2.3 | 2.7 | 0.6 | 1.2 | 0.7 | 0.6 |
| P | X | 0.7 | 0.6 | 0.4 | 0.8 | 1.5 | ////////// |
| * | Y | 1.4 | 2.8 | 0.9 | 0.5 | 0.2 | ////////// |
| * | Z | 1.6 | 2.9 | 1.0 | 0.9 | 1.5 | 0.3 |
| L | X | 0.4 | 1.3 | 0.5 | 2.1 | 1.7 | ////////// |
| * | Y | 1.4 | 3.1 | 1.7 | 0.4 | 0.7 | ////////// |
| * | Z | 1.5 | 3.4 | 1.7 | 2.1 | 1.8 | 0.3 |

Negative "G" Restraint Data Master
Median Differences between Orientations
+Gz to -Gz
Restraint Type - V

| Subject | Axis | Head | Shoulder | Knee | Foot | Stick | Off-Seat |
|---|---|---|---|---|---|---|---|
| B | X | 0.1 | 0.4 | 0.7 | 0.4 | 2.5 | ////////// |
| * | Y | 2.5 | 5.0 | 1.2 | 1.4 | 0.7 | ////////// |
| * | Z | 2.5 | 5.0 | 1.4 | 1.4 | 2.6 | 1.4 |
| F | X | 0.1 | 0.0 | 0.3 | 0.6 | 1.2 | ////////// |
| * | Y | 2.2 | 3.4 | 0.3 | 0.6 | 0.1 | ////////// |
| * | Z | 2.2 | 3.4 | 0.4 | 0.9 | 1.2 | 0.9 |
| R | X | 0.4 | 0.3 | 0.5 | 0.2 | 1.2 | ////////// |
| * | Y | 2.0 | 2.7 | 0.3 | 0.7 | 0.3 | ////////// |
| * | Z | 2.0 | 2.7 | 0.5 | 0.7 | 1.2 | 1.1 |
| P | X | 0.1 | 0.2 | 0.3 | 0.0 | 1.4 | ////////// |
| * | Y | 1.9 | 4.4 | 0.5 | 0.6 | 0.3 | ////////// |
| * | Z | 1.9 | 4.4 | 0.6 | 0.6 | 1.5 | 1.4 |
| L | X | 0.1 | 0.3 | 0.4 | 0.6 | 2.5 | ////////// |
| * | Y | 1.7 | 3.2 | 1.0 | 0.7 | 1.0 | ////////// |
| * | Z | 1.7 | 3.2 | 1.1 | 0.9 | 2.7 | 0.9 |

| Subject | Axis | Head | Shoulder | Knee | Foot | Stick | Off-Seat |
|---|---|---|---|---|---|---|---|
| B | X | 0.8 | 1.3 | 0.0 | 0.9 | 3.3 | ////////// |
| * | Y | 2.3 | 4.1 | 1.6 | 0.5 | 0.8 | ////////// |
| * | Z | 2.4 | 4.3 | 1.6 | 1.0 | 3.4 | 0.9 |
| F | X | 0.1 | 0.1 | 0.4 | 0.7 | 1.4 | ////////// |
| * | Y | 2.0 | 4.4 | 0.4 | 0.6 | 0.5 | ////////// |
| * | Z | 2.0 | 4.4 | 0.6 | 0.9 | 1.4 | 0.5 |
| R | X | 0.1 | 0.0 | 0.5 | 0.4 | 0.7 | ////////// |
| * | Y | 2.3 | 2.6 | 0.2 | 1.3 | 0.2 | ////////// |
| * | Z | 2.3 | 2.6 | 0.5 | 1.4 | 0.7 | 0.4 |
| P | X | 0.1 | 0.1 | 0.5 | 0.0 | 0.9 | ////////// |
| * | Y | 1.5 | 3.9 | 0.6 | 0.6 | 0.0 | ////////// |
| * | Z | 1.5 | 3.9 | 0.8 | 0.6 | 0.9 | 1.1 |
| L | X | 0.4 | 0.4 | 0.4 | 0.8 | 2.0 | ////////// |
| * | Y | 1.7 | 3.6 | 1.4 | 0.1 | 0.6 | ////////// |
| * | Z | 1.8 | 3.6 | 1.5 | 0.8 | 2.1 | 0.5 |

Negative "G" Restraint Data Master
Median Differences between Orientations
+Gz to -Gz
Restraint Type - VI

CONVERSION OF RAW DATA

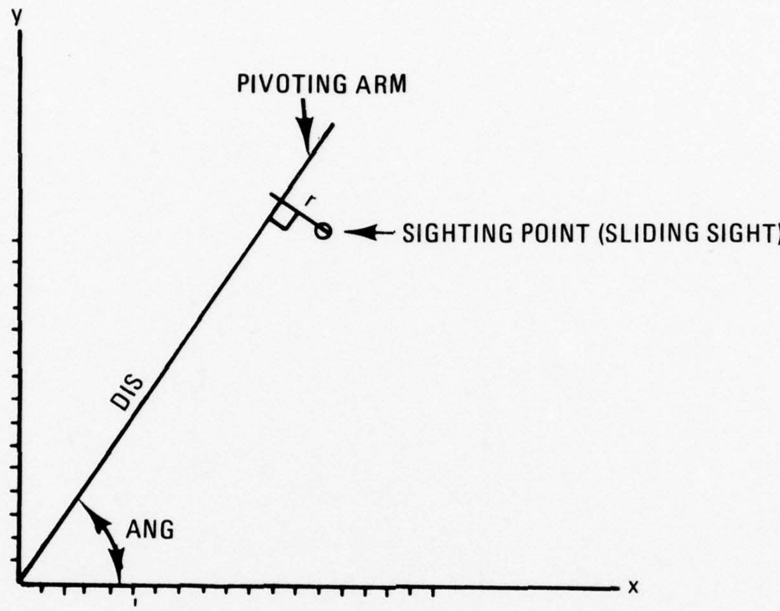



Figure 1
Conversion of Raw Data

All raw data are in the form of polar coordinates with a constant sight offset ($r = 2.25$ inches, 5.72 cm). In order to resolve the offset, and obtain usable polar coordinates, use the following formulae:

$$ang' = ang - ARCTAN\ (r/DIS)$$

$$DIS' = (DIS^2 + r^2)^{1/2}$$

In order to convert raw data to rectangular coordinates (x,y), use the following formulae:

$$x = (DIS^2 + r^2)^{1/2} COS(ang - ARCTAN\ (r/DIS)) = (DIS')COS(ang')$$

$$y = (DIS^2 + r^2)^{1/2} SIN(ang - ARCTAN\ (r/DIS)) = (DIS')SIN(ang')$$

$$z = (X^2 + Y^2)^{1/2}$$

# DRAFT OF MILITARY SPECIFICATION
# FOR
# RESTRAINT SYSTEMS

MILITARY SPECIFICATION

SYSTEM, AIRCREW INTEGRATED RESTRAINT
AND PARACHUTE ATTACHMENT;
GENERAL SPECIFICATION FOR

This specification has been approved by the
Naval Air Systems Command
Department of the Navy

# 1. SCOPE

1.1 Scope. This specification establishes design performance and construction requirements and associated design evaluation and production quality assurance requirements for an aircrew restraint and parachute attachment system capable of providing (1) the necessary aircrew ground and in-flight mobility and in-flight restraint, (2) restraint during emergency egress (ejection), (3) the means for attaching the parachute to the aircrewmember and distributing parachute opening loads safely, (4) ease of normal attachment/divestment of system, and (5) rapid divestment for emergency ditching or ground fire rescue.

1.1.1 Purpose of Equipment. Aircrew restraint systems are employed to provide protection from injury, minimization of undesirable movement, and a more stable operating platform when under the influence of adverse accelerative conditions, thereby enhancing aircrew performance of in-flight tasks, increasing the weapons system's mission effectiveness, and decreasing the risk of aircrew or aircraft loss. The parachute attachment systems are employed to provide rapid, secure attachment or disengagement of the parachute from the aircrew member and to safely distribute the parachute opening loads.

1.2 Safety of Flight Considerations. The proper design of an aircrew restraint system is critical for insuring control of the aircraft under adverse accelerative conditions encountered in both normal flight and air combat and for regaining control of an uncontrolled aircraft. Impairment of crew mobility can result in excessive and rapid onset of fatigue, can inhibit crew ability to detect enemy threats and initiate appropriate evasive action, and can generate or contribute to the worsening of situations which could jeopardize the safety of the aircraft, the safety of other aircraft, the safety of ship and shore installations, and the successful completion of the mission. Failure of the equipment to provide effective aircrew restraint, however, can also result in jeopardy to men and equipment by inducing a condition where control of the aircraft is no longer possible, or where the need for regaining control of an aircraft that is departed or

uncontrolled cannot be met, or by interfering with the aircrewman's ability to successfully escape an aircraft which cannot be controlled. In addition, failure of the equipment to provide rapid, secure attachment/disengagement of the parachute to the aircrew member and the safe distribution of parachute opening loads can delay manning of aircraft and impair aircrew safety during and after attempted escape from a disabled aircraft.

## 2. APPLICABLE DOCUMENTS.

2.1 The following documents of the issue in effect on date of invitation for bids or request for proposal form a part of the specification to the extent specified herein.

SPECIFICATIONS

Federal

| | |
|---|---|
| QQ-M-40 | Magnesium Alloy Forgings |
| QQ-C-320 | Chromium Plating (Electrodeposited) |
| QQ-P-416 | Plating, Cadmium (Electrodeposited) |

Military

| | |
|---|---|
| MIL-P-116 | Preservation Packaging, Methods of |
| DOD-D-1000 | Drawings, Engineering and Associated Lists |
| MIL-M-3171 | Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion |
| MIL-S-5002 | Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems |
| MIL-C-5541 | Chemical Conversion Coatings on Aluminum and Aluminum Alloys |
| MIL-C-6021 | Castings, Classification and Inspection of |
| MIL-H-6088 | Heat Treatment of Aluminum Alloys |
| MIL-M-6857 | Magnesium Alloy Castings, Heat Treatment |
| MIL-H-6875 | Heat Treatment of Steels (Aerospace Practice, Process for) |
| MIL-F-7179 | Finishes and Coatings: Protection of Aerospace Weapons Systems, Structures and Parts, General Specification for |

| | |
|---|---|
| MIL-F-7190 | Forgings, Steel for Aircraft and Special Ordnance Applications |
| MIL-A-8625 | Anodic Coatings for Aluminum and Aluminum Alloys |
| MIL-M-8650 | Mockups: Aircraft, Construction of |
| MIL-E-9426 | Escape Systems, Requirements Conformance Demonstrations and Performance Tests for: General Specification for |
| MIL-F-18264 | Finishes: Organic, Weapons System, Application and Control of |
| MIL-S-18471 | Seat System, Ejectable, Aircraft, General Specification for |
| MIL-A-21180 | Aluminum Alloy, Castings, High Strength |
| MIL-H-81200 | Heat Treatment of Titanium and Titanium Alloys |
| MIL-D-81514 | Device, Restraint Harness Take-Up, Inertial-Locking, Powered-Retracting: General Specification for |
| MIL-S-83490 | Specifications, Types and Forms |
| WR-62 | Naval Weapons Requirements Specifications and Standards: Use of |

STANDARDS

Military

| | |
|---|---|
| MIL-STD-143 | Specifications and Standards, Order of Precedence for the Selection of |
| MIL-STD-210 | Climatic Extremes for Military Equipment |
| MIL-STD-480 | Configuration Control - Engineering Changes, Deviations and Waivers |
| MIL-STD-481 | Configuration Control - Engineering Changes, Deviations, and Waivers (Short Form) |
| MIL-STD-882 | System Safety Program for Systems and Associated Subsystems and Equipment: Requirement for |
| MIL-STD-889 | Dissimilar Metals |

| | |
|---|---|
| MIL-STD-961 | Outline of Forms and Instructions for the Preparation of Specifications and Associated Documents |
| MIL-STD-1472 | Human Engineering Design Criteria for Military Systems, Equipment, and Facilities |
| MIL-STD-2067 | Aircrew Automated Escape Systems, Reliability and Maintainability (Draft) |

HANDBOOKS

Military

| | |
|---|---|
| MIL-HDBK-5 | Metallic Materials and Elements for Aerospace Vehicle Structures |
| MIL-HDBK-132 | Protective Finishes |
| MIL-HDBK-693 | Magnesium and Magnesium Alloys |
| MIL-HDBK-694 | Aluminum and Aluminum Alloys |

PUBLICATIONS

Air Force - Navy

| | |
|---|---|
| ANA Bulletin No. 147 | Specifications and Standards of Non-government Organizations Released for Flight Vehicle Construction |

Naval Air Systems Command

| | |
|---|---|
| NAVAIR 13-1-6.2 | Aviation Crew System Manual - Personnel Parachutes |

Naval Air Engineering Center

| | |
|---|---|
| NAEC-ACEL Report No. 533 | Anthropometry of Naval Aviators - 1964 (DDC No. AD626322) |

Naval Aerospace Medical Research Laboratory

| | |
|---|---|
| NAMRL Report No. 1130 | Selected Bivariate Anthropometric Distributions Describing a Sample of Naval Aviators - 1964 |

U.S. Air Force

| | |
|---|---|
| AMRL-TR-705 | Anthropometry of Female Aircrew - 1972 |
| AMRL-TDR-62-128 | Investigation of a Personnel Restraint System for Advanced Manned Flight Vehicles |

3. REQUIREMENTS.

3.1 Selection of Material and Standard Parts. The selection of materials, standard parts, processes, corrosion protection, and design features significant in adequate corrosion behavior and capable of successfully withstanding the effects of other specified environmental conditions shall assure achievement of requisite product quality for life support and life-saving equipments.

3.1.1 Materials. Materials employed in the system shall conform to applicable specifications and shall be as specified herein and on applicable drawings. Materials which are not covered by government specifications, or which are not specifically described herein, shall be of the best quality, of the lightest practicable weight, and suitable for the purpose intended and shall be approved by the Government procuring activity. Particular care shall be given to close-fitting parts in the choice of both materials and corrosion prevention practices. Unless otherwise specified, the material components (except for the metallic parts) used in the construction of the parachute attachment portions of the system shall have been manufactured not more than 24 months prior to the date of delivery of the equipment, or in cases where the useful life of the material exceeds 10 years, not more than 20 percent of the useful life of the material prior to its delivery.

3.1.1.1 Metal Parts. All metal parts shall be of the corrosion-resistant type or treated in a manner to render them resistant to corrosion. Unless suitably protected against electrolytic corrosion, dissimilar metals, as defined in MIL-STD-889, shall not be used in contact with each other. These considerations shall be applied also to the system's interface with the seat and/or aircraft in which it is to be installed. General design information governing usage of metals is furnished in MIL-HDBK-5. General design information for aluminum and aluminum alloys is provided in MIL-HDBK-694.

3.1.1.1.1 Heat Treatment. Heat treatment of aluminum parts and steel parts shall be in accordance with MIL-H-6088 and MIL-H-6875, respectively. Heat treatment of magnesium alloy castings (when such parts have been permitted in accordance with 3.1.1.1.4) shall be in accordance with MIL-M-6857. Heat treatment of titanium and titanium alloy parts shall be in accordance with MIL-H-81200.

3.1.1.2 Castings. Castings used in the escape system shall conform to the requirements of MIL-C-6021. In addition, aluminum alloy castings shall conform to the requirements of MIL-A-21180.

3.1.1.1.3 Steel Forgings. Steel forgings used in the escape system shall conform to the requirements of MIL-F-7190. Critical steel forgings shall meet the requirements for MIL-F-7190 Grade A forgings.

3.1.1.1.4 Magnesium and magnesium alloys. Magnesium and magnesium alloy parts shall not be used without the express approval of the Government procuring activity. The contractor shall describe the intended application, protective measures planned, and the composition of parts adjacent to the proposed usage. General design information for magnesium and magnesium alloys is presented in MIL-HDBK-693.

3.1.1.1.4.1 Magnesium Alloy Forgings. Magnesium alloy forgings shall conform to the requirements of QQ-M-40.

AD-A058 995 NAVAL AIR TEST CENTER PATUXENT RIVER MD F/G 1/3
AIRCREW PERSONNEL RESTRAINT SUBSYSTEMS DEFINITION OF DEFICIENCI--ETC(U)
AUG 78 R BASON, J ETHEREDGE
UNCLASSIFIED NATC-SY-28R-78 NL

3 OF 4
AD
A058995

END
DATE
FILMED
11-78
DDC

CONT

4

995

3.1.1.2 Nonmetallic Components. Nonmetallic components of the system shall be designed to minimize deterioration caused by abrasion and/or exposure to sunlight, microorganisms, dirt, moisture, heat, fuel, hydraulic and lubricating oil, grease, salt spray, flue gases, and, where direct contact with humans occurs, perspiration and body oils. Protection shall be provided for those nonmetallic components, particularly nylon lines, for which strength degradation associated with abrasion or exposure-induced deterioration can endanger the system user. All nonmetallic materials shall be flame resistant and shall not produce toxic gases when subjected to high temperature or flame.

3.1.1.3 Fungus-Proof Materials. To the greatest extent practicable, the materials used in the system shall not be nutrients for fungi. If materials that are nutrients for fungi must be utilized, such materials shall be treated with a fungicidal agent safe for subsequent long-term direct contact with humans and approved by the Government procuring agency.

3.1.1.4 Labels.

3.1.1.4.1 Label Application. Placement of labels shall avoid causing excessive chafing/wear of the label, weakening or damage to the fabric surface upon which the label is affixed, discomfort to the wearer, or interference with smooth adjustment of any part of the system.

3.1.1.4.2 Shade and Size Marking. The aircrew restraint and parachute attachment system and their component parts shall be marked or ticketed, by any commercial method, to insure a uniform shade throughout the garment and for the proper assembly of the system. No metal fastening device or sewn-on ticket shall be used. The shade and size markings shall be accomplished by the use of an ink pad numbering machine, rubber stamp, or pencil provided the markings do not show through to the outerside of the garment and are not deleterious to the material marked. The markings, which are placed on the seam allowance, shall not be visible on the outerside. The adhesive type shade and size marking tickets may be used for the shade and size markings provided they conform to paragraph 3.1.1.4.2.1. The assembled parachute attachment portions of the system shall not contain any shade or size marking tickets.

3.1.1.4.2.1 Adhesive Shade and Size Marking Tickets. The adhesive shade and size marking tickets shall be fabricated from paper with a thermo-activated adhesive applied to one side. The adhesive shall not discolor or damage the cloth and the adhesive mass shall not adhere to the cloth upon removal of the ticket. The heat used to attach the thermo-activated tickets shall not stiffen, harden, scorch, or damage the cloth in any manner.

3.1.2 Corrosion Protection. Corrosion protective practices employed in the manufacture of aircrew restraint and parachute attachment systems and their components shall be in accordance with MIL-STD-889 for dissimilar metals and with the MIL-F-7179 requirements for exterior surfaces. Magnesium alloy parts shall be treated in accordance with the MIL-M-3171 requirements for Type VII Treatment, including surface sealing.

3.1.2.1 Finishes. Protective coatings and finishes shall not crack, chip, or scale during normal service or in the herein specified extremes of atmospheric

conditions. Surface treatments, coatings, and finishes shall conform to MIL-S-5002 or surface treatments herein specified. General guidance in the application and control of organic finishes is provided in MIL-F-18264 and in MIL-HDBK-132.

3.1.2.2 Anodizing. All aluminum and aluminum alloy parts, except those subject to wear or falling under the provisions of 3.1.2.2.1, shall be anodized in accordance with MIL-A-8625, Type II anodic coating. Anodic coatings for all aluminum and aluminum alloy parts subject to wear shall conform to MIL-A-8625, Type III, except for parts which are expensive and would normally be reworked during overhaul. For these parts, chromium plating in accordance with QQ-C-320 shall be used.

3.1.2.2.1 Chemical Surface Treatment. For aluminum and aluminum alloy parts not subject to wear, abrasion, or erosion, chemical conversion surface treatment in accordance with MIL-C-5541 may be used in lieu of anodizing.

3.1.2.3 Plating. Steel parts in contact with aluminum or aluminum alloys shall be cadmium plated in accordance with QQ-P-416, Type II, Class I.

3.1.2.4 Cleanliness. Cleaning practices employed in the manufacturing of the aircrew restraint and parachute attachment system and its components shall be in accordance with MIL-P-116 and the governing Federal/military procurement specifications. All nonprotected critical functioning or close tolerance surfaces shall be cleaned immediately prior to the application of lubricants. Internal parts of assemblies shall be cleaned as applicable prior to assembly, and precautions shall be taken to prevent postcleaning contamination of parts.

3.1.3 Selection of Specifications and Standards. Specifications and standards for necessary commodities and services not specified herein shall be selected in accordance with MIL-STD-143 and WR 62. A partial listing of approved (MIL-STD-143 Group II) nongovernment organization specifications and standards is furnished in ANA Bulletin Number 147. Contractor-prepared specifications and specification control drawings shall comply with MIL-STD-961.

3.1.4 Drawings. Drawing requirements shall be specified by the procuring activity in accordance with DOD-D-1000 instructions. Generally, all categories of drawings established in DOD-D-1000 will be required. Unless otherwise directed by the Government procuring activity, all drawings shall conform to the requirements established in DOD-D-1000 for Form 2 Drawings.

3.1.5 Construction.

3.1.5.1 Cutting. The fabric/textile portions of the restraint and parachute attachment system shall be cut in strict accordance with the patterns conforming to the applicable drawings. Following Government procurement activity acceptance of the system through its Approval for Service Use (ASU) and/or Release for Production, the baseline configuration patterns shall become Government-owned patterns. These shall be employed to develop the working patterns. The working patterns shall be identical to the Government patterns. Neither the Government patterns nor the working patterns shall be altered in any manner except through formal engineering change approval systems and, if required, design reevaluation.

3.1.6 Seams and Stitching. All the seams, stitch types, stitches per inch, and back stitching shall conform to the applicable drawings. Each row of stitching shall be straight and parallel to the seam edge. The straightness of the stitching in any row shall be maintained within a tolerance of plus or minus 1/32 inch (1 mm). The thread breaks, skips, and runoffs shall be overstitched not less than 1/2 inch (13 mm). The thread tension shall be maintained so that there shall not be loose or tight stitching and the lock shall be embedded in the materials sewn together. All the seam edges shall be properly forced out and shall not contain any folds greater than 1/8 inch (3 mm). No seam or component shall be twisted, puckered, or pleated, and no part of the fabric component shall be caught in an unrelated operation or seam. All the thread ends shall be trimmed to a length of 1/4 inch (6 mm) or less.

3.1.7 Color. The aircrew restraint and parachute attachment systems and their component parts, which do or might leave the aircraft during an escape, must be an unobtrusive color to reduce the likelihood that such pieces or components will assist in the apprehension of any of the crewmembers during the enemy evasion phase of their escape.

3.2 General Design Requirements. The general objective to be achieved in the design of an aircrew restraint and parachute attachment system shall be in accordance with the following:

a. Crewmember Accommodation. The system shall accommodate the 1st through the 99th percentile male and female aircrew member wearing applicable personnel protective equipment and shall permit a comfortable condition in which the efficiency and effectiveness of the aircrew member are optimized. The number of different sizes and special fitting efforts/procedures shall be kept to a minimum. All anthropometric data for the 1st through the 99th percentile male aircrew members shall be in accordance with NAEC-ACEL Report Number 533 and NAMRL Report Number 1130. Data for female aircrew members shall be in accordance with AMRL-TR-705 of April 1972 (Air Force).

b. Comfort. Any portions of the system worn by the aircrew member shall be lightweight and comfortable both in and out of the cockpit. Particular attention shall be directed toward comfort in the ready room, during preflight and postflight operations, and during ingress and egress of the aircraft. Other considerations shall include, but not be limited to, thermal comfort, blood flow restriction, pressure points upon the aircrew member, fatigue/nuisance reduction, and compatibility with survival, escape, enemy evasion, and enemy confrontation activities. Hardware shall be mounted so that it avoids contact with bony prominences of the body, regardless of the load vector placed upon the hardware.

c. Ease of Use. Any portion of the system worn by the aircrew member shall be easy to don and doff, be simple in format, and avoid complex routing. Adjustment of any portion of the system or its component parts shall be easily executed, whether accomplished outside or inside the cockpit. The adjustment and attachment points shall be foolproof, incapable of binding or jamming, free from slippage or inadvertent actuation once adjusted, and designed to conform to the minimal biomechanical strength capabilities for a 1st percentile aircrew member

insofar as attachment and full adjustment forces are concerned. Environmental obstacles, such as cockpit structures, shall be taken into account when designing such adjustment and attachment points so that the action described herein is easily performed by 1st through the 99th percentile aircrew members.

d. Quick Release Fittings. Any portion of the system designed to be worn by the aircrew member outside of the aircraft, and its releases, shall be designed so that all components can be released from attachment to the ejection seat in an emergency, using one release point (manual emergency release). The individual quick release fittings shall be designed so that they can be released either automatically, manually, or a combination thereof, using a minimal number of manual operations/release points. Release action shall be simple, not susceptible to inadvertent releases, capable of being effected with either hand, whether in hot, cold, wet, or other adverse conditions (including darkness), while wearing equipment appropriate to the aircrew member's task (including gloves). The aircrew member shall be able to discriminate, in total darkness and while influenced by adverse environmental conditions, whether quick release fittings or other restraint locking devices are locked or unlocked. The quick release fittings shall be mounted so that there is no physical hazard presented to the aircrewman by the fittings and so that actuation of the fittings cannot cause injury, damage to equipment, degradation of escape performance, snagging upon any item of equipment worn by the aircrew member, or snagging upon crewstation equipment.

e. Cockpit Compatibility. The design of the aircrew restraint and parachute attachment systems shall be compatible with the aircrew station, including its seat and associated parts, in which the system will be used. The restraint system shall allow the aircrew member full access to all aircraft flight controls, combat weapons systems, flight displays, and emergency egress controls under all flight conditions and all accelerative vectors.

f. Equipment Compatibility. The aircrew restraint and parachute attachment system shall be compatible with the stowage and operation of specified survival equipment, appropriate to the aircrewman's task, and shall not hinder ready availability/operation of such designated equipment for rescue, survival, or enemy evasion.

g. Mobility. The restraint system shall provide sufficient freedom of motion inside the aircraft for the aircrew member to operate and reach all flight controls, communications and electronic equipment, flight instruments, navigation devices, crew-operated weapons, first aid equipment, underseat stowage compartments (if applicable), and to turn in the seat so as to provide maximum rearward view without turning the head more than 60 degrees. The system shall not degrade normal or necessary in-flight vision requirements in any manner. Any portion of the restraint system worn by the aircrew member outside of the aircraft shall provide sufficient freedom of motion for the aircrew member to walk, run, climb steep inclines (up and down), swim, and undertake other survival, enemy evasion, and enemy confrontation efforts without the system causing physical hindrance.

h. Restraint. The restraint system shall provide effective retention of the aircrew member's body in the design functional position under all accelerative conditions and shall not degrade control of the aircraft, interfere with the initiation of emergency egress, allow impact/contact cockpit or canopy structures, or to permit injury from adverse accelerative loading.

i. Parachute Attachment. When restraint and parachute attachment systems are combined or integrated into one assembly, and when the system is designed to be separate from but connected to the parachute assembly, the geometry of the system shall be such that inadvertent release/detachment from the parachute portion is not possible. Neither the parachute attachment portion nor the restraint portion of the assembly shall in any way interfere with the operation of the other. The parachute attachment to the system shall be accomplished in such a manner as to present no risk of injury or damage to the aircrew member or equipment during parachute deployment and opening, or during any other phase of flight or emergency egress.

3.2.1 Human Factors General Design Requirements. Shall be in accordance with MIL-STD-1472. Other considerations shall include but not be limited to:

a. Sizing. The number of different sizes of garments, harnesses, or assemblies used in the restraint system and parachute attachment system shall be kept to a minimum and shall be capable of fitting 1st through 99th percentile aircrew members without resorting to modifications to the system. The number of special fitting procedures shall also be minimized.

b. Adjustment. Adjustment of the restraint system and parachute attachment portion shall be capable of being effected by the wearer without assistance. The means of adjusting the system will be simple in format, easy to use, and will retain the selected adjustment until released by the wearer.

c. Aircrew Accommodation. The restraint system and parachute attachment portion shall be in accordance with paragraph 3.2. The anatomical and anthropometric differences between males and females shall be taken into account when designing such a system so that proper use of the system will not result in discomfort, degradation of ability, or injury to the wearer as a result of these differences.

3.2.2 General Service Environmental Conditions. Inasmuch as parts of the system may be permanently installed in cockpits which are frequently open for extended periods, particularly those cockpits in which access is obtained through the open canopy, while other parts might be worn by the aircrew member to and from the aircraft and might be stored in less than optimal conditions during periods of nonuse, the aircrew restraint and parachute attachment system and its component parts can be expected to be exposed to an extreme range of environmental conditions normally associated with externally located equipment. This system and its components shall be capable of withstanding with a minimum of upkeep and of functioning properly following storage in, or during use in, the following environments:

a. <u>Aircraft Installed</u>. Those portions of the system normally installed in the aircraft, either permanently or semipermanently, shall be capable of withstanding with a minimum of upkeep and of functioning properly following storage or use in the following climatic extremes specified in MIL-STD-210 for each of the seven spheres of operation as defined in 1.2 of MIL-STD-210 (basic document):

(1) 2.1, Probable hot thermal extremes.

(2) 2.2, Probable cold thermal extremes.

(3) 2.3, Probable high humidity extremes.

(4) 2.4, Probable low humidity extremes.

(5) 2.8.2, Blowing sand.

(6) 2.8.3, Blowing dust.

(7) 2.9, Extreme atmospheric pressure.

In addition, environmental conditions shall include fungus, shock, acceleration, vibration, sunshine, rain, salt spray/fog, condensate, and fuel gases.

b. <u>Aircrew Member Worn</u>. Those portions of the system designed to be worn by the individual aircrew member shall be capable of withstanding with a minimum of upkeep and of functioning properly following exposure to or use in:

(1) Grease, oil fuels.

(2) Cleaning fluids.

(3) Perspiration, body oils, body fluids.

(4) Dust, dirt, grime.

(5) In-service storage conditions.

(6) Abrasion.

(7) Smoke.

(8) Food.

(9) Ultraviolet/infrared radiation.

(10) Parachute opening shock.

(11) Ejection forces.

(12) Windblast.

(13) Paint.

(14) Oxygen.

3.2.3 Escape Environmental Conditions. To insure proper functioning of an aircrew restraint and parachute attachment system following escape initiation, the system and its component parts shall be capable of functioning properly and in correct sequence without sustaining or causing damage that might injure the ejectee, damage personal protective garments and/or survival equipments, or degrade escape system performance following exposure to environmental conditions, including (but not limited to) explosive decompression, windblast, shock, acceleration, vibration, and temperature shock associated with the escape envelope specified in the applicable escape system specification.

3.3 Specific Design Requirements.

3.3.1 System Subsystem Design. The aircrew restraint and parachute attachment system shall include components/subsystems to accomplish the following:

a. Provide effective containment/restraint of aircrew torso.

b. Attach aircrew containment/restraint to the seat.

c. Provide effective controlled upper torso mobility/restraint.

d. Provide effective controlled pelvic restraint.

e. Attach aircrew to parachute.

f. Attach aircrew to survival equipment container or individual items (if applicable).

3.3.1.1 General Requirements for Torso Restraint/Containment. Designs for torso restraint/containment systems shall provide the following:

a. Thoracic restraint shall distribute loads over the entire chest area and maintain normal chest contour (to avoid constricting the lungs and heart).

b. Abdominal restraint shall contain the semi-fluid abdominal mass to minimize excursion of the abdominal organs (reference AMRL-TDR-62-128).

c. The pelvic region shall be held down and back against the seat by retaining the crests of the ilium. Pelvic restraint shall not restrict lateral movement.

d. The torso restraint system must prevent submarining and off-seat displacement with minimal discomfort and without threat of injury to the aircrew member when in the active mode and create no discomfort to aircrew members when in the passive mode.

e. Restraint components shall be structurally compatible with inflight, escape, and crash G forces.

f. Restraint shall maintain the aircrew member in a natural (sitting upright) posture.

g. The restraint system elastic response shall avoid dynamic overshoot.

h. Pelvic restraint shall be compatible with the torso restraint system, particularly in the area of permissible movement.

i. The restraint system must restrict spinal column loading of the upper thoracic vertebrae by restraining the lower torso and thighs. Shoulder harness restraints must permit some upward motion to avoid accumulating an injurious load on the upper vertebrae. The contractor shall develop and present for Government procuring activity concurrence a plan for ascertaining the amount of movement needed to prevent injurious upper vertebral loading.

j. The restraint system shall not fail at the maximum forward/upward acceleration level when supporting a 99th percentile aircrew member wearing the bulkiest and heaviest equipment normally issued to the aircrew member who would be using that type of restraint system. Additional provisions shall be made for the absorption and/or distribution of energy by the system so that any acceleration applied to the aircrew member is evenly distributed over a large area, without causing injury or discomfort, while at the same time preventing impact with cockpit or canopy structures.

3.3.1.2 Upper Torso Mobility/Restraint. An upper torso restraint subsystem shall provide the following features:

a. Zero interference/nuisance during flight, as required and when so selected by the aircrew member, yet provide instantly available restraint during all phases of flight.

b. The capability to deprogram or adjust the force resisting upper torso forward motion without loss of automatic inertia retraction and locking features required for escape.

c. The capability of the aircrew member to select the range of G forces at which the deprogrammed system would be overridden by an automatic restraining/haul-back system.

d. Unlimited frequency, repeatable, manually commanded upper torso haul-back under all flight conditions. Power sources for this feature shall not cause corrosion of the device or in any manner jeopardize the escape haul-back feature, nor shall the loss of power for the aircraft effect the function of the haul-back system. The use of the repeatable restraint/haul-back system shall not require or induce reconditioning or maintenance tasks in excess to a comparable, nonrepeatable haul-back system.

(1) The haul-back force shall be directly responsive to the force generated by the acceleration of the aircrew member and shall not cause injury or otherwise incapacitate the aircrew member. The contractor shall present for Government procuring activity concurrence a plan for ascertaining retraction time, velocity, and forces applied to the aircrew member.

(2) The haul-back system shall be capable of manually or automatically actuating a lock system so that retraction of the upper torso results in positive locking of the retraction mechanism, with no forward motion, until deselected by the aircrewman.

(3) The haul-back force shall be capable of being eased off when so selected by the aircrew member.

e. The upper torso restraint subsystem shall prevent unwanted upward as well as forward body motion.

f. The haul-back device shall conform to the requirements of MIL-D-81514, as modified by the preceding, in order to provide upper torso haul-back for escape positioning, powered independently of the aircraft power source.

3.3.1.3 Pelvic Restraint Subsystem. The pelvic restraint subsystem shall include, but not be limited to, the following features:

a. The ability to retract the aircrew member automatically against the seat, repeatedly, without manually resetting the system. This retraction feature shall accommodate G loads of up to -4 Gz and off-seat displacement of up to 5 inches (12.7 mm) and should be available and programmable through a range of G loads at the aircrew member's option.

b. The capability of sensing off-seat displacement and automatically and instantly correcting for that displacement by the use of a haul-back feature.

c. An automatic haul-back system, independent of the power source for the programmable haul-back feature, which would position the aircrew member immediately upon initiation of the ejection system.

d. Power sources for any repeatable haul-back system shall not cause corrosion of the devices, nor shall the loss of power for the aircraft effect the functioning of these devices. The use of the programmable haul-back feature shall not induce or require excessive reconditioning or maintenance tasks.

e. The haul-back force shall be sufficient to overcome any force generated by the acceleration of the aircrew member and shall not cause injury or otherwise incapacitate the aircrewman. The contractor shall present for Government procuring activity concurrence a plan for ascertaining retraction time, velocity, and forces applied to the aircrew member.

3.3.1.4 Attachment of the Restraint to the Seat. The strength of the restraint system attachment to the seat of the aircraft shall be at least equal to 1.5 times the load limit of the seat attachment to the airframe. The design of the restraint system and its means for attachment to the seat shall ensure that the seat and the restraint system act as an integrated load bearing system.

3.3.2 Electromagnetic Compatibility. Operation of the repeatable haul-back system or any other powered element of the system shall not interfere with any aircraft electronic systems, nor shall on-board electromagnetic radiation, either from within or exterior to the aircraft, cause inadvertent operation of any haul-back feature or any other powered element of the system.

3.3.3 Escape Haul-Back. Cyclic use of the repeated retraction feature or loss of its power sources through aircraft loss of power, disconnection, rupture, breakage, or other malfunctions or damage shall not degrade or preclude escape haul-back system operation following actuation of the escape system.

3.3.4 Elements Crossing Seat-Aircraft Interface. Elements of the aircrew restraint and parachute attachment system shall be capable of automatic disconnection during escape or as the seat is removed for maintenance. These elements also shall be capable of self-alignment and automatic reconnection during seat reinstallation following its normal removal. If the elements involved contain fluids or gases, during disconnection, they shall automatically seal to prevent the loss, contamination, blockage, or fodding of the systems. During automatic reconnection, the seals shall automatically displace to permit normal flows.

3.4 Reliability.

3.4.1 Reliability Program. The contractor shall establish, implement, and document a reliability program in accordance with MIL-STD-2067. The program plan shall be submitted within 60 days following award of contract to the Government procuring activity for approval. In the event the system is being procured as part of an escape system, the program plan shall be integrated into and submitted with that for the escape system.

3.4.2 Probability of Success. The probability of success shall conform to the apportioned reliabilities necessary for the escape system to meet each of the MIL-STD-2067 defined escape system reliabilities.

3.4.3 Fail-safe Operation. Critical functional elements which have several modes of operation shall be designed to ensure that any failure of such elements will not compromise safe escape capability or normal flight/mission aircrew performance.

3.4.4 Vulnerability. The contractor shall initiate during the design conceptualization phase, and shall prosecute actively throughout the balance of the system development and service release effort, a vulnerability analysis program closely affiliated with the reliability, maintainability, safety, and human factors programs herein required. The program plan shall be submitted to the Government procuring activity for approval within 60 days following award of contract. In the event the system is being procured as part of an escape system, the program plan shall be

integrated into and submitted with that for the escape system. The vulnerability analysis effort shall assume that nondeliberate actions will damage the system and shall ascertain what damage may result, the effect(s) of such damage upon the system, and means for preventing (preferrable) or minimizing/neutralizing such damage and/or system degradation. Vulnerability analysis shall consider, but shall not be limited to, the following damage modes:

a. Damage while the system is installed in the aircraft.

b. Damage induced during system/component removal from, and/or installation in, the aircraft.

c. Damage occurring while the system/components have been removed (either damage of removed elements or of elements exposed within the aircraft as a result of removal of other system elements).

d. Damage resulting from incorrect/improper maintenance (i.e., overtorquing, failure to connect, erroneous connections, etc.).

e. Damage induced by aircraft/weapons systems failures.

f. Damage induced by hostile actions.

3.5 Maintainability.

3.5.1 Maintainability Program. The contractor shall establish, implement, and document a maintainability program in accordance with MIL-STD-2067. The program shall be submitted to the Government procuring activity within 60 days following award of contract. In the event the system is being procured as part of an escape system, the program plan shall be integrated into and submitted with that for the escape system.

3.6 Design Safety. The contractor shall conform to the general requirements of MIL-STD-882 when designing the aircrew restraint and parachute attachment system to ensure system design safety both as part of an escape system and separately. When identifying potential problems/hazards, the contractor shall develop information which defines the probability of the problem/hazard occurrence. If this system is being procured as part of an escape system, the system safety program shall be integrated into and executed as an element of the escape system safety program.

3.7 Data.

3.7 System Data Requirements. The data requirements required herein shall be complied with. Reports, including copies of applicable films and instrumentation records, shall be furnished in the format and quantities indicated for each test performed in accordance with paragraphs 4.2.1, 4.2.2.1.1, and 4.2.2.1.2. The data and records submitted shall be legible and suitable for analysis to permit the Government procuring activity and its support activities to conduct an evaluation of the system and its performance capabilities.

3.7.1 Maintenance Instruction. The contractor shall prepare and submit to the Government procuring activity for approval written instructions concerning applicable maintenance items, including specific directions for inspection, repair, return to service, and preventive maintenance for components worn by the individual aircrew member. The maintenance documents shall comply with the format specified for inclusion in NAVAIR 13-1-6.2 (Personnel Parachutes). If any part of the restraint and parachute attachment system is being procured as an item normally furnished as part of or normally attached to an escape system or weapons system, the applicable maintenance documents shall be submitted in the format detailed above and in a format suitable for use in the seat Maintenance Instruction Manual.

3.7.2 Operating Instruction.

3.7.3 Detailed System Component/Subsystem Specification. The contractor shall prepare and submit to the Government procuring activity for approval specifications conforming to the requirements of MIL-S-83490 for Form 2 specifications for components/subsystems design, test, manufacture, and quality assurance procedures not adequately defined by military or federal specifications or standards or acceptable nongovernmental organization specifications or standards. Guidelines for preparing specifications are furnished in MIL-STD-961. When necessary to modify a Government specification to clarify or define more adequately components, subsystems, or systems, the contractor shall advise the Government procuring activity, requesting guidance whether to provide such modification for Government issuance or to prepare a contractor specification.

3.7.4 Detailed System Component Drawings. Drawing requirements shall be specified by the Government procuring activity in accordance with DOD-D-1000 instructions. Generally, all levels of drawings established in DOD-D-1000 will be required during the development and qualification of a system for production.

3.8 Design Quality Assurance.

3.8.1 System/Component Qualification. Prior to qualification of the restraint and parachute attachment system for installation and service use, the requirements of 4.3 shall be satisfied and the effective implementation of an acceptable production inspection program conforming to the requirements of 4.2.2 shall have been demonstrated to the satisfaction of the Government procuring activity.

3.8.1.1 Mock-up. The contractor shall prepare an equipment mock-up. If the restraint/parachute attachment system is being procured as a part of an escape system, the contractor shall install the system in an appropriate manner in the escape system mock-up. The mock-up shall be representative of the planned final design and shall be constructed in general accordance with the principles and requirements of MIL-M-8650. The mock-up shall depict accurately the location and/or routing of all components, controls, connections, and devices. All restraint and parachute attachment controls and manually activated devices shall be mocked up in a manner permitting operation of at least the control handles. The mock-up review shall include provisions to incorporate appropriate flotation, survival, and clothing items where interface and operation is involved. For the greatest benefit

to the program, the mock-up review should be scheduled and convened as early in the program as practicable. The mock-up shall be reviewed by representatives of the Government procuring activity and/or its field activities.

3.8.1.2 Engineering Proofing Article. The contractor shall prepare a restraint and parachute attachment system engineering proofing article, representative of the finished product. Parts need not be manufactured by production processes. If the system is being procured as part of an escape system, or if the system involves retrofitting of existing escape systems, the contractor shall install the restraint and parachute attachment system engineering proofing article in the appropriate manner in the escape system engineering proofing article or in the actual seat in which the system is to be retrofitted. For programs involving retrofitting of existing escape systems, installation of the retrofit shall be conducted in accordance with formalized installation instructions prepared in accordance with paragraph 3.14.2 of MIL-S-18471F(AS) and shall be observed by representatives of the Government procuring activity and/or its field activities. It is desirable that the engineering proofing article review occur sufficiently prior to commencement of system performance tests to permit incorporation of design changes resulting from review into the test articles.

3.8.1.3 Production Proofing Article. (To be determined)

3.8.1.4 First Article. (To be determined)

3.8.2.1 Baseline Configuration for Qualification Testing. The approved restraint and parachute attachment system engineering proofing article, demonstrating form, fit, and manual functioning, shall constitute the baseline configuration for service release testing. Within 30 days following approval of the engineering proofing article, the contractor shall issue drawings sufficient to describe completely the baseline configuration provided for service release testing. If the restraint and parachute attachment system is being procured as part of an escape system, or as part of an escape system retrofit, the restraint and parachute attachment system, including the necessary connection required for testing, shall be treated as a separate part for the purpose of establishing testing baseline criteria.

3.8.2.2 Final Baseline Configuration. The final baseline configuration, that which is released and approved by the Government procuring activity for installation and service use, shall consist of the baseline configuration at service release testing with such modifications as are required to obtain restraint and parachute attachment performance, strength, environmental protection, and component qualification conforming to the herein specified requirements. Accomplishment of such modifications shall be at no additional cost to the Government and shall require prior approval by the Government procuring activity. Within 45 days following the completion and approval of all testing, the contractor shall compile and submit to the Government procuring activity for approval, drawings sufficient to describe completely the final baseline configuration. Accompanying the final baseline configuration drawings shall be a report describing each of the differences between the final and service release testing baseline configurations and furnishing information concerning the reasons for making the changes.

3.8.2.3 Production Article. The restraint and parachute attachment system, and the elements thereof delivered under contract for incorporation in production and/or in-service aircraft, shall be configured in accordance with the Government procuring activity approved final baseline configuration as modified by engineering changes prepared, submitted and approved in accordance with MIL-STD-480 or MIL-STD-481, as applicable, and shall be equivalent to, or better than, the Production Proofing Article (PPA) in all respects, including (but not limited to) design, construction, workmanship, structural integrity, performance, and quality. Each production article shall be capable of successfully completing those MIL-E-9426 tests and conditionings imposed upon the service release test articles and the in-process design compatibility inspection articles. Evidence of noncompliance shall constitute cause for the Government procuring activity to revoke the system service release and to require correction of the deficiencies and demonstration of the corrective action adequacy to ensure compliance.

3.9 Workmanship. Workmanship shall be of the highest quality to assure optimum performance, reliability, and service life. Particular attention shall be given to freedom from defects, burrs, and sharp edges; accuracy of dimensions, radii, fillets, and markings of parts and assemblies; thoroughness of welding, brazing, painting, and riveting; alignment of parts; and tightness of assembly screws and bolts. After completion of the final assembly, the system shall be thoroughly cleaned and all loose thread, lint, and foreign matter shall be completely removed. The system shall not contain any nonspecified hole, tear, cut, burn, needle chew, spot, stain, and/or weakening defect. The metal components shall not be misaligned or distorted, or contain any corrosion, scale, pit, dent, nick, burr, sliver, crack, or sharp edge. Snap fasteners shall be securely clinched without distortion, cracking, splitting, or cutting of the cloth or webbing. Snap fastener studs and sockets shall be properly aligned so that, when snapped together, they shall not cause a noticeable bulge or twist to the material. Because of the emergency and life support use of the system, the importance of providing a product of uniformly excellent quality cannot be overemphasized. Any garment or harness element of the system shall be uniform in quality and free from irregularities or defects which could adversely affect performance, reliability, or durability. The system shall conform to the quality and grade of product established by this specification. The occurrence of defects shall not exceed the acceptance criteria established herein.

## 4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facility suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Quality Assurance Tests. Quality assurance tests required herein are classified as follows:

a. Component/subsystem qualification tests.

b. Escape system compatibility tests.

c. System environmental conditioning tests.

d. System design verification tests for service release.

e. Maintainability and reliability tests.

f. Production quality control inspections and tests.

4.2.1 Component/Subsystem Qualification Tests. Component/subsystem qualification tests shall be conducted in accordance with applicable military specifications and standards. The contractor shall prepare for Government procuring activity approval qualification test plans and specifications for critical components/subsystems for which military specifications or standards do not exist. Such specifications shall conform to the requirements of MIL-S-83490 for Form 2 (unless otherwise specified by contract or Contract Data Requirements List) specifications. In preparing the specifications, the contractor shall be guided by the requirements and practices set forth in MIL-STD-961.

4.2.2 Quality Assurance Program for Acceptance of Delivery.

4.2.2.1 Manufacturing/Receiving/In-Process Inspections. The contractor shall develop, obtain approval from Government procuring activity or its designee, and implement plans and procedures for manufacturing (in-house), receiving, and assembly in-process inspections for ensuring the production and delivery of systems and components of consistently high quality commensurate with their personnel safety function. The inspection plans and procedures shall include both nondestructive and destructive testing, as necessary, in addition to normal gaging type inspection. In developing the plans and procedures, the contractor shall give consideration to, and document fully, the following and other pertinent aspects:

a. The nature of potential deficiencies/nonconformities in each part and assembly.

b. The effect of each potential deficiency/nonconformity upon system performance, reliability, maintainability, vulnerability, resistance to service environments, safety, and compliance to specification and design requirements.

c. Available techniques for detecting each potential deficiency/nonconformity.

d. The probabilities of detecting each potential deficiency/nonconformity with each available inspection/testing technique.

e. The cost of using each technique.

4.2.2.1.1 Nondestructive Testing of Critical Parts. Following assembly, the contractor shall identify those system parts/components which, should they structurally fail during flight operation or escape system operation, or during application of crash loads, would result in injury to aircrew members. The contractor shall recommend to the Government procuring activity a program of nondestructive testing for assuring acceptable production quality of the identified critical parts/components.

4.2.2.1.2 Destructive Testing. The contractor shall identify those system parts/components which require destructive testing to ensure continuing compliance with design performance, reliability, or other requirements and shall develop sampling plans, conditioning and testing plans, and acceptance/rejection criteria for each such part/component.

4.2.2.1.3 Inspection of Production Units. Production aircrew restraint systems shall satisfactorily complete a nondestructive functional test program prior to acceptance under contract. The program shall be developed by the prime contractor and submitted via the Naval Plant Representative or the local Defense Contract Administration Office, the National Parachute Test Range, and the Naval Air Development Center to the Government procuring activity for approval. The test program shall consist of sufficient functional tests to demonstrate overall control system performance.

4.2.2.1.4 Vendor/Supplier Quality Assurance Programs. The contractor shall develop and/or review vendor/supplier quality assurance plans and procedures to ensure their adequacy for assuring requisite quality levels in delivered parts.

4.2.2.2 Examination for Preparation for Delivery. Inspection of the preservation, packaging, packing, and marking shall be in accordance with Section 5.

4.3 System Qualification Requirements.

4.3.1 First Article Inspection. The first article inspection of the restraint and parachute attachment system shall consist of examinations and tests for all of the requirements of this specification.

4.3.1.1 First Article Samples. Unless otherwise specified, as soon as practicable after the award of the production contract or order, or the release of the system for production following the completion of the development phase of a contract, the manufacturer shall submit to the government-designated inspection activity two restraint and parachute attachment systems of any size (if applicable) for each type (if applicable) specified in the contract or order. The samples shall be representative of the construction, workmanship, components, and materials to be used during production. If the restraint and parachute attachment system is being procured as a part of an escape system, then the first article samples shall be submitted along with the first article samples of the escape system. When a contractor is in continuous production of these articles from contract to contract, submission of further first article inspection samples on the new contract may be waived at the discretion of the Government procuring activity. Approval of the first article inspection samples or the waiving of the first article inspection does

not preclude the requirements for performing the quality conformance inspection. The first article inspection samples shall be furnished to the Government as directed by the contracting officer.

4.3.1.2 First Article Inspection Documentation. Upon completion of the first article inspection, all the applicable inspection reports and, when applicable, recommendations and comments pertinent for use in monitoring production will be forwarded to the cognizant government activity. One of the approved first article inspection samples will be returned to the manufacturer for use in monitoring production. The remaining sample will be destroyed in the first article inspection. Neither first article sample shall be considered to constitute or be used as part of the production quantity to be delivered under the contract or order.

4.3.1.3 Retention of Qualification. The retention of qualification shall consist of periodic verification to determine compliance of the qualified article(s) with the requirements of this specification. The time and method of periodic verification shall be determined by the activity responsible for the Qualified Products List and shall be included in the Notice of Qualification letter.

4.4 Preparation for Delivery. An inspection lot size shall be expressed in units of one fully prepared shipping container containing articles of one type and size (as applicable), fully prepared for delivery from essentially the same materials and components. The unit of product shall be one shipping container, containing restraint and parachute attachment systems of one type and size (as applicable), fully prepared for delivery with the exception that it need not be sealed. In the event that the restraint and parachute attachment system is being procured as an integral part of an escape system, preparation for delivery shall conform to MIL-S-18471F.

5. PREPARATION FOR DELIVERY

6. NOTES

6.1 Intended Use. The aircrew integrated restraint and parachute attachment systems, assemblies, and components covered by this specification are intended for use by personnel operating or performing functions in aircraft utilizing restraint systems which integrate with the aircrew automated escape systems.

6.2 Order Data. Procurement documents should specify the following:

a. Title, number, and date of this specification.

b. Data required.

c. Selection of applicable levels of packaging and packing.

d. Whether any additional special markings are required.

e. Package design drawing and prototype test data provide address of approving activity.

f. Aeronautical Equipment Service Record.

g. Preservation, packaging, and packing requirements applicable to: GSE and SSE and logistic support items unless provided in the detail specification or order.

6.3 Qualification. With respect to products requiring qualification, awards will be made only for products which are, at the time set for opening bids, qualified for inclusion in the applicable Qualified Products List, whether or not such products have actually been listed by that date. The attention of the suppliers is called to this requirement and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Commander, Naval Air Systems Command, Department of the Navy, Washington, D.C., 20361; however, authorization for qualification of products shall be obtained from the Commander, National Parachute Test Range, El Centro, California, 92243.

6.4 Laboratory Information. The successful bidder will be furnished with the name of the quality conformance inspection facility including the laboratory and Government activity responsible for conducting the inspection program at the time of the award. The cost of the tests and examination of samples initially submitted from a lot shall be borne by the Government, whether the tests and examinations are conducted by a Government laboratory or by a laboratory selected by the cognizant Government activity. Samples from a rejected lot shall not be resubmitted for tests and examination without the approval of the contracting officer. The cost of the tests and examinations of samples resubmitted from a reworked lot or from a new lot, which is necessitated by the rejection of a previous lot, shall be borne by the manufacturer whether the tests and examinations are conducted by a Government laboratory or by a laboratory selected by the cognizant Government activity.

6.5 Data. For the information of contractors and contracting officers, except for the data specified in 6.5.1, applicable documents listed in Section 2 of this specification, or referenced lower-tier documents, need not be prepared for the Government and shall not be furnished to the Government unless specified in the contract or order. The data to be furnished shall be listed on DD Form 1423 (Contractor Data Requirements Lists), which shall be attached to and made a part of the contract or order.

6.5.1 Contractor Efforts Under Tasks Designated as Design Objectives. In the event that parts of this specification or separate tasks contractually are identified as "design objectives," the contractor shall examine each task identified to determine (a) the parameters of the task or problem, (b) possible alternative approaches for accomplishing the task or for solving the problem, (c) potential benefits and problems posed by each alternative approach or solution, and (d) the optimum approach or solution if one or more are feasible for incorporation in the escape system. The contractor shall submit to the Naval Air Systems Command; the Naval Air Development Center; the National Parachute Test Range; the Naval Air Test Center; and the Naval Ordnance Station, Indian Head, for each such task

and problem a letter report describing the investigation conducted and the contractor's findings and recommendations. The reports should be submitted prior to production proofing kit approval.

## ACKNOWLEDGEMENT

1. In a project of this magnitude, it is quite impossible to acknowledge the debt to all who have assisted in its conduct. The following persons have been especially helpful, however, and to all of them the authors are deeply grateful.

NAVAL AIR TEST CENTER RESEARCH ASSISTANTS

HM1 James a Fultz, USN

TD1 Tamridge D. Kinnison, USN (Retired)

TD2 Gerald P. Ficek, USN

AEROMEDICAL SAFETY OPERATIONS (AMSO) PHYSIOLOGISTS

2. These personnel administered and supervised the completion of the Aircrew Personnel Restraint Questionnaire.

| | |
|---|---|
| LT Charles L. Anderson | LT David B. Kelly |
| LT Guy R. Banta | LCDR Wilton W. McIntosh |
| LCDR James A. Brady | LT Jerry C. Patee |
| LCDR Robert L. Elzy | LCDR Harold T. Pheeny |
| LCDR John F. Greear III | LCDR D. Gary Smith |

3. The authors wish to also acknowledge the support so generously furnished by LCDR Allen B. Miller at the Naval Safety Center and LCDR Paul A. Furr at the Naval Aerospace Medical Research Laboratory.

4. Finally, but most important, we acknowledge our indebtedness to the subjects who gave so generously of their time and effort, and tolerated discomfort and inconvenience cheerfully and without complaint during their many hours as subjects. Their wholehearted cooperation made the study a pleasure to perform.

LT Thomas N. Presecan

HM1 James A. Fultz

PR2 David Douglas

PR1 Peter Ricket

Mr. Gordon LeGuire

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|---|
| 1. REPORT NUMBER<br>SY-28R-78 | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle)<br>AIRCREW PERSONNEL RESTRAINT SUBSYSTEMS DEFINITION OF DEFICIENCIES AND REQUIREMENTS | | 5. TYPE OF REPORT & PERIOD COVERED<br>FINAL REPORT<br>6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s)<br>LT R. BASON, USN<br>HM2 J. ETHEREDGE, USN | | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>NAVAL AIR TEST CENTER<br>NAVAL AIR STATION<br>PATUXENT RIVER, MARYLAND 20670 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS<br>A53153120535/6531000001 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS<br>NAVAL AIR SYSTEMS COMMAND<br>DEPARTMENT OF THE NAVY<br>WASHINGTON, D.C. 20361 | | 12. REPORT DATE<br>24 AUGUST 1978<br>13. NUMBER OF PAGES<br>215 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) | | 15. SECURITY CLASS. (of this report)<br>UNCLASSIFIED<br>15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

| | | |
|---|---|---|
| HEAD MOVEMENT UNDER -Gz | RESTRAINT | BODY MOVEMENT UNDER -Gz |
| OFF-SEAT DISPLACEMENT | ACCELERATION STRESS | -Gz |
| UPPER TORSO STRETCH | AIRCREW RESTRAINT DEFICIENCIES | EJECTION SEATS |
| SPINAL STRETCH UNDER -Gz | MA-2 INTEGRATED TORSO HARNESS | |
| BIOMECHANICS UNDER -Gz | SPINAL COLUMN | |

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

NAVAIRTESTCEN was tasked to examine reported problems with aircrew torso restraint garments. Five sources of information were used for the investigation into the reported problems: Development of a logic tree for analysis of reported inadequate restraint of aircrews; examination of Medical Officer's Reports from 1969 through 1976 pertaining to ejections from aircraft in which the MA-2 Integrated Torso Harness was a part of the restraint system; examination of Unsatisfactory Reports for the same period; solicitation of an Aircrew Personnel Restraint Questionnaire from aircrew assigned to high performance tactical aircraft; and a laboratory study of the biomechanics of -Gz

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20.
restraint. The MA-2 Integrated Torso Harness was found to be inadequate in all respects for -Gz restraint and ineffective as a restraint garmet for -Gx and lateral (Gy) accelerative forces. Data were developed defining the effects of negative Gz upon the body, suggesting that it produces two separate components, off-seat travel and body stretch, each of which requires specific treatment by any proposed restraint system. Recommendations are made for immediate improvement of deficiencies in the design of the restraint harness and its related subsystems, and emphasis is placed on the need for reevaluation of restraint needs, mobility needs, and the comfort of the crewmember in future design efforts. Further research, development, and testing of a variety of harnesses is urged.

Naval Air Test Center, Patuxent River, Maryland 20670

AIRCREW PERSONNEL RESTRAINT SUBSYSTEMS
DEFINITION OF DEFICIENCIES AND REQUIREMENTS,
FINAL REPORT

24 August 1978 215 pages
SY-28R-78
A53153120535/6531000001

Approved for public release; distribution unlimited.

1. Head Movement Under -Gz
2. Off-Seat Displacement
3. Upper Torso Stretch
4. Spinal Stretch Under -Gz
5. Biomechanics Under -Gz
6. Restraint
7. Acceleration Stress
8. Aircrew Restraint Deficiencies
9. MA-2 Integrated Torso Harness
10. Spinal Column
11. Body Movement Under -Gz
12. -Gz
13. Ejection Seats

Naval Air Test Center, Patuxent River, Maryland 20670

AIRCREW PERSONNEL RESTRAINT SUBSYSTEMS
DEFINITION OF DEFICIENCIES AND REQUIREMENTS,
FINAL REPORT

24 August 1978 215 pages
SY-28R-78
A53153120535/6531000001

Approved for public release; distribution unlimited.

1. Head Movement Under -Gz
2. Off-Seat Displacement
3. Upper Torso Stretch
4. Spinal Stretch Under -Gz
5. Biomechanics Under -Gz
6. Restraint
7. Acceleration Stress
8. Aircrew Restraint Deficiencies
9. MA-2 Integrated Torso Harness
10. Spinal Column
11. Body Movement Under -Gz
12. -Gz
13. Ejection Seats

Naval Air Test Center, Patuxent River, Maryland 20670

AIRCREW PERSONNEL RESTRAINT SUBSYSTEMS
DEFINITION OF DEFICIENCIES AND REQUIREMENTS,
FINAL REPORT

24 August 1978 215 pages
SY-28R-78
A53153120535/6531000001

Approved for public release; distribution unlimited.

1. Head Movement Under -Gz
2. Off-Seat Displacement
3. Upper Torso Stretch
4. Spinal Stretch Under -Gz
5. Biomechanics Under -Gz
6. Restraint
7. Acceleration Stress
8. Aircrew Restraint Deficiencies
9. MA-2 Integrated Torso Harness
10. Spinal Column
11. Body Movement Under -Gz
12. -Gz
13. Ejection Seats

Naval Air Test Center, Patuxent River, Maryland 20670

AIRCREW PERSONNEL RESTRAINT SUBSYSTEMS
DEFINITION OF DEFICIENCIES AND REQUIREMENTS,
FINAL REPORT

24 August 1978 215 pages
SY-28R-78
A53153120535/6531000001

Approved for public release; distribution unlimited.

1. Head Movement Under -Gz
2. Off-Seat Displacement
3. Upper Torso Stretch
4. Spinal Stretch Under -Gz
5. Biomechanics Under -Gz
6. Restraint
7. Acceleration Stress
8. Aircrew Restraint Deficiencies
9. MA-2 Integrated Torso Harness
10. Spinal Column
11. Body Movement Under -Gz
12. -Gz
13. Ejection Seats

Naval Air Test Center, Patuxent River, Maryland 20670

AIRCREW PERSONNEL RESTRAINT SUBSYSTEMS
DEFINITION OF DEFICIENCIES AND REQUIREMENTS,
FINAL REPORT

24 August 1978 215 pages
SY-28R-78
A53153120535/6531000001

Approved for public release; distribution unlimited.

1. Head Movement Under -Gz
2. Off-Seat Displacement
3. Upper Torso Stretch
4. Spinal Stretch Under -Gz
5. Biomechanics Under -Gz
6. Restraint
7. Acceleration Stress
8. Aircrew Restraint Deficiencies
9. MA-2 Integrated Torso Harness
10. Spinal Column
11. Body Movement Under -Gz
12. -Gz
13. Ejection Seats

Naval Air Test Center, Patuxent River, Maryland 20670

AIRCREW PERSONNEL RESTRAINT SUBSYSTEMS
DEFINITION OF DEFICIENCIES AND REQUIREMENTS,
FINAL REPORT

24 August 1978 215 pages
SY-28R-78
A53153120535/6531000001

Approved for public release; distribution unlimited.

1. Head Movement Under -Gz
2. Off-Seat Displacement
3. Upper Torso Stretch
4. Spinal Stretch Under -Gz
5. Biomechanics Under -Gz
6. Restraint
7. Acceleration Stress
8. Aircrew Restraint Deficiencies
9. MA-2 Integrated Torso Harness
10. Spinal Column
11. Body Movement Under -Gz
12. -Gz
13. Ejection Seats

Naval Air Test Center, Patuxent River, Maryland 20670

AIRCREW PERSONNEL RESTRAINT SUBSYSTEMS
DEFINITION OF DEFICIENCIES AND REQUIREMENTS,
FINAL REPORT

24 August 1978 215 pages
SY-28R-78
A53153120535/6531000001

Approved for public release; distribution unlimited.

1. Head Movement Under -Gz
2. Off-Seat Displacement
3. Upper Torso Stretch
4. Spinal Stretch Under -Gz
5. Biomechanics Under -Gz
6. Restraint
7. Acceleration Stress
8. Aircrew Restraint Deficiencies
9. MA-2 Integrated Torso Harness
10. Spinal Column
11. Body Movement Under -Gz
12. -Gz
13. Ejection Seats

Naval Air Test Center, Patuxent River, Maryland 20670

AIRCREW PERSONNEL RESTRAINT SUBSYSTEMS
DEFINITION OF DEFICIENCIES AND REQUIREMENTS,
FINAL REPORT

24 August 1978 215 pages
SY-28R-78
A53153120535/6531000001

Approved for public release; distribution unlimited.

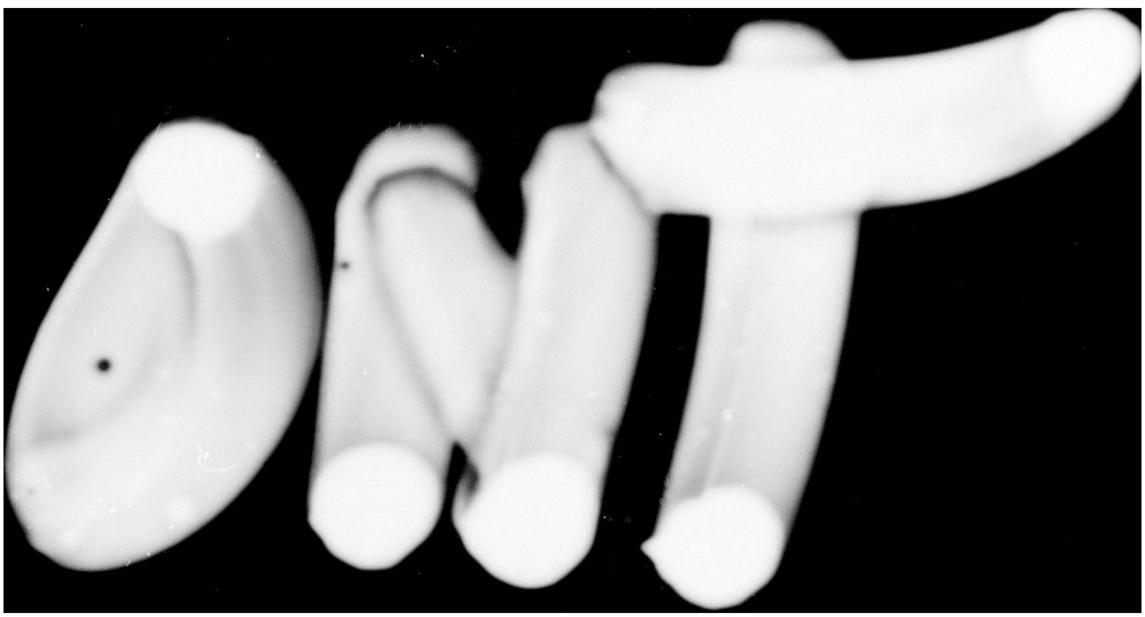
1. Head Movement Under -Gz
2. Off-Seat Displacement
3. Upper Torso Stretch
4. Spinal Stretch Under -Gz
5. Biomechanics Under -Gz
6. Restraint
7. Acceleration Stress
8. Aircrew Restraint Deficiencies
9. MA-2 Integrated Torso Harness
10. Spinal Column
11. Body Movement Under -Gz
12. -Gz
13. Ejection Seats

END

DATE
FILMED

1-78

DDC



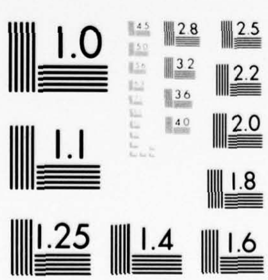
AD-A058 995 NAVAL AIR TEST CENTER PATUXENT RIVER MD F/G 1/3
AIRCREW PERSONNEL RESTRAINT SUBSYSTEMS DEFINITION OF DEFICIENCI--ETC(U)
AUG 78 R BASON, J ETHEREDGE
UNCLASSIFIED NATC-SY-28R-78 NL

4 OF 4
AD
A058995


END
DATE
FILMED
4-79
DDC

4 OF 4

AD
A058995




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SUPPLEMENTARY

INFORMATION

REPORT NO: SY-28RE-78
AIRTASK NO: A53153120535/6531000001
WORK UNIT NO:
DATE: 26 December 1978

COPY NO. 115

# NAVAL AIR TEST CENTER
# TECHNICAL REPORT ERRATA

AD-A058995

**FROM**
Commander, Naval Air Test Center, Patuxent River, Maryland 20670

**TO**
Commander, Naval Air Systems Command, Washington, D.C. 20361

| REPORT NO. | AIRTASK | WORK UNIT | DATE |
|---|---|---|---|
| SY-28R-78 | A53153120535/6531000001 | | 24 August 1978 |

**REPORT TITLE**
Aircrew Personnel Restraint Subsystems Definition of Deficiencies and Requirements; Final Report

IT IS REQUESTED THAT ALL RECIPIENTS OF THE ABOVE REPORT INCORPORATE THE FOLLOWING CORRECTIONS:

Delete page 86 and replace with attached page 86.



**DISTRIBUTION**
Distribution List follows on pages 2 through 7

**SIGNATURE**
R. L. Breckon
R. L. BRECKON
By direction



79 01 08 062

DISTRIBUTION:

CAPT James B. Wildman, USN (15)
Director, Crew Systems Division
Naval Air Systems Command - NAVAIR-531
Washington, D.C. 20361

Mr. Fred Guill (2)
Naval Air Systems Command - NAVAIR-531C
Washington, D.C. 20361

CAPT N. B. Endo (1)
Director, Program Management
Naval Air Systems Command - NAVAIR-532
Washington, D.C. 20361

Mr. Henry A. Fedrizzi (1)
Life Support
Naval Air Systems Command - NAVAIR-340B
Washington, D.C. 20361

Mr. T. P. Mastic (1)
Plans Policy and Program Branch
Naval Air Systems Command - NAVAIR-4111
Washington, D.C. 20361

Commander
U.S. Naval Air Development Center (4)
Warminster, Pennsylvania 18974

Commanding Officer (4)
National Parachute Test Range
El Centro, California 92243

Commanding Officer (3)
Naval Ordnance Center
Codes 51, 512, 515
Indian Head, Maryland 20640

Commander (2)
Naval Weapons Center
Codes 6222, 3273
China Lake, California 93555

Commander (4)
Naval Air Force
U.S. Atlantic Fleet
Naval Air Station
Norfolk, Virginia 23511

Commander (1)
Naval Air Force
U.S. Pacific Fleet
Code 72
Box 1210
Naval Air Station, North Island
San Diego, California 92135

Commanding General (4)
Fleet Marine Force, Pacific
FPO San Fancisco, California 96610

Commanding General (4)
Fleet Marine Force, Atlantic
Norfolk, Virginia 23511

Commanding General (1)
Third Marine Aircraft Wing
Marine Corps Air Station, El Toro
Santa Ana, California 92709

Commander (4)
Naval Safety Center
Naval Air Station
Norfolk, Virginia 23511

Director (2)
Naval Weapons Engineering Support Activity
Codes ESA-11, ESA-19
Washington Navy Yard
Washington, D.C. 20374

Commanding Officer (1)
Naval Aerospace Medical Research Laboratory
Naval Air Station
Pensacola, Florida 32508

LCDR Paul Furr, MSC, USN (1)
Naval Aerospace Medical Research Laboratory
Naval Air Station
Pensacola, Florida 32508

Commanding Officer (1)
Naval Aerospace Medical Institute
Naval Air Station
Pensacola, Florida 32508

Commanding Officer (1)
Navy Fighter Weapons School
Naval Air Station, Miramar
San Diego, California 92145

CDR E. T. Smith, USN (1)
Executive Officer
VF-43
Naval Air Station, Oceana
Virginia Beach, Virginia 23460

LCDR Harold Pheeny, MSC, USN (1)
Aviation Medical Safety Operations
Training Wing Six
Naval Air Station
Pensacola, Florida 32508

LCDR D. Gary Smith, MSC, USN (1)
Aviation Physiology Training Service
Naval Regional Medical Center, Portsmith
Branch Dispensary
Naval Air Station
Norfolk, Virginia 23511

LCDR Robert L. Elzy, MSC, USN (1)
Branch Clinic
Naval Air Station
Jacksonville, Florida 32212

LT Charles Anderson, MSC, USN (1)
Aerospace Physiology Training Unit
Naval Regional Medical Center
Regional Dispensary
Naval Air Station, Miramar
San Diego, California 92145

LCDR Jerry C. Patee, MSC, USN (1)
Aerospace Physiology Training Unit
Naval Regional Medical Center, Long Beach
Marine Corps Air Station
El Toro Dispensary
Santa Ana, California 92709

LCDR David B. Kelly, MSC, USN (1)
Aeromedical Safety Operations
Commander Light Attack Wing
U.S. Pacific Fleet
Code 021
Naval Air Station
Lemoore, California 93245

LT Guy Banta, MSC, USN (1)
Code AMSO
Branch Clinic
Naval Air Station
Meridian, Mississippi 39301

Mr. Byron C. Solomonides (1)
Rockwell International Aircraft
4300 East Fifth Avenue
Columbus, Ohio 43216

Mr. Wolf J. Hebenstreit (1)
Boeing Aerospace Company
Seattle, Washington 98124

Mr. John Jewell (1)
Martin-Baker Aircraft Company
Higher Denham Uxbridge
Middlesex, England

Stencel Aero Engineering Corporation (1)
P.O. Box 5836
Asheville, North Carolina 28804

Stanley Aviation Corporation (1)
P.O. Box 20308
Denver, Colorado 80220

Mr. Robert Manzuk (1)
Teledyne Ryan Incorporated
2701 Harbor Drive
San Diego, California 92138

Northrop Aircraft Corporation (1)
3901 W. Broadway
Hawthorne, California 90250

Mr. Armand Aronne (1)
Grumman Aerospace Corporation
Bethpage, Long Island, New York 11714

Mr. E. R. Atkins (1)
Vought Corporation
P.O. Box 5907
Dallas, Texas 75222

Naval Plant Representative Office (1)
Lockheed Aircraft Corporation
Burbank, California 91503

Mr. Robert McIntyre (1)
McDonnell Douglas Aircraft Corporation
Douglas Aircraft Company
Long Beach, California 90846

Ronald L. Huston, Ph. D. (1)
College of Engineering, Loc #112
University of Cincinnati
Cincinnati, Ohio 45221

LCDR James Brady, MSC, USN (1)
Aerospace Physiology Training Branch
Naval Regional Medical Center (Code 08)
Corpus Christi, Texas 78419

LCDR John F. Greear III, MSC, USN (1)
Aviation Physiology Training Service
Naval Regional Medical Center, Portsmith
Branch Dispensary
Naval Air Station
Norfolk, Virginia 23511

USAABAR (1)
Fort Rucker
Dothan, Alabama 36360

Dayton T. Brown (1)
555 Church Street
Bohenia, Long Island, New York 11716

Talley Industries (1)
3800 North Central Avenue
Phoenix, Arizona 85012

M. Steinthal & Company, Incorporated (1)
2525 Palmer Avenue
New Rochelle, New York 10801

Pacific Scientific Company (1)
1346 South State College Boulevard
Anaheim, California 92803

H. Koch & Sons (1)
5410 E. LaPalma Avenue
Anaheim, California 92807

Fairchild Industries, Incorporated (1)
20301 Century Boulevard
Germantown, Maryland 20767

Deputy Inspector General Safety (1)
Headquarters, Air Force Inspection & Safety Center
Norton Air Force Base
San Bernardino, California 92409

Aeronautical Systems Division (1)
Life Support SPO
Wright-Patterson Air Force Base, Ohio 45433

| | |
|---|---|
| United States Air Force Systems Command<br>School of Aerospace Medicine<br>Brooks Air Force Base<br>San Antonio, Texas 78235 | (1) |
| Commanding General<br>U.S. Army Aviation Systems Command<br>P.O. Box 209<br>St. Louis, Missouri 63166 | (1) |
| DDC | (12) |

## DEFINITION OF GRAVITATIONAL VECTORS

In order to facilitate future inquiries into the effects of gravitational acceleration in flight, standard terms are used throughout the report and in the body of data. The following definitions of gravitational vectors are derived from The Bioastronautics Data Book (NASA SP-3006, Second Edition, Parker & West, Ed.).

| Linear Motion | Inertial Resultant of Body Acceleration | | |
|---|---|---|---|
| | Physiological Descriptive (Sys. 3) | Physiological Standard (Sys. 4) | Vernacular Descriptive |
| Forward | (1,2) Transverse P-A G, Prone G Back to Chest G | -Gx | Eyeballs In |
| Backward | Transverse A-P G Supine G Chest to Back G | +Gx | Eyeballs Out |
| Upward | Positive G | +Gz | Eyeballs Down |
| Downward | Negative G | -Gz | Eyeballs Up |
| To Right | Left Lateral G | +Gy | Eyeballs Left |
| To Left | Right Lateral G | -Gy | Eyeballs Right |